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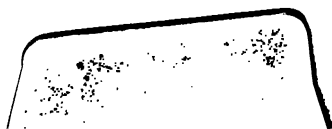
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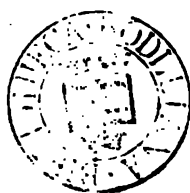


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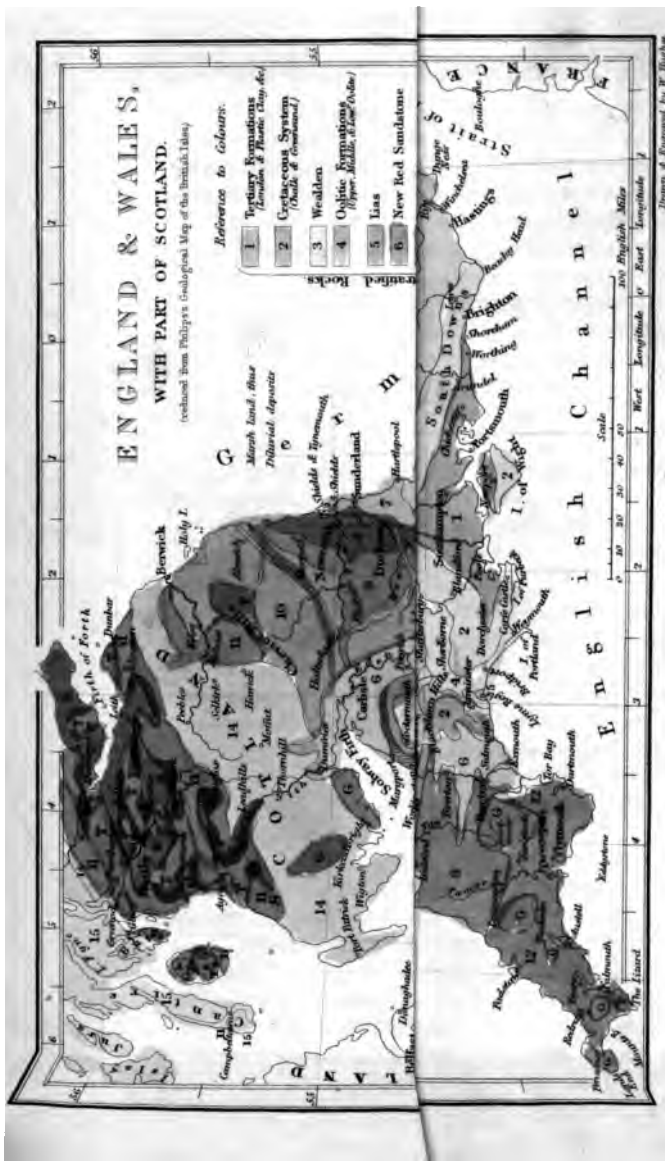


ENGLAND & WALES,
WITH PART OF SCOTLAND.

(redrawn from Phillips's Geological Map of the British Isles)

Reference to Colours:

- | | |
|---|--|
| 1 | Tertiary Formations
<i>(Ardenia & Plastic Clay, etc.)</i> |
| 2 | Cretaceous System
<i>(Oolite & Gravelstone)</i> |
| 3 | Walden |
| 4 | Oolite Formations
<i>(Upper, Middle, & Lower Oolite)</i> |
| 5 | Lias |
| 6 | New Red Sandstone |

Marsh land, thus
industrial disaster*Drawn & Engraved by W. Hughes.*

London Published by the Socy for promulgating Christian Knowledge, 1850.

OUTLINES
OF
BRITISH GEOLOGY,

CHIEFLY INTENDED TO ILLUSTRATE

THE GEOLOGY OF ENGLAND AND WALES,

WITH SOME NOTICE OF THAT OF

SCOTLAND AND IRELAND.

TO WHICH IS APPENDED,

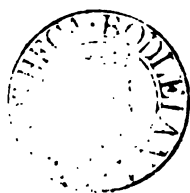
A GLOSSARY OF TERMS USED IN GEOLOGY AND MINERALOGY.

“Geology is intimately connected with the existence and distribution of every form of vegetable and animal life, the sources of commerce, and the wealth and prosperity of nations; and the study of its various and stupendous phenomena opens to the mind the profoundest views of the power, prescience, and wisdom of the Author of nature.”—*Anonymous*.

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PREFACE.



BUT little more than half a century has elapsed since Geology began to assume the character of a science, through the labours and observations of Werner, a Professor of Mineralogy at Freiberg, in Saxony, who was the first to attempt to trace the order of the superposition of rocks, and to classify them under different names, expressive of their character and position in the general scale. His observations, however, being confined to a limited portion of Germany, led him to adopt some erroneous opinions and theories with regard to the nature and production of trap rocks, which gave rise to long-continued and intemperate discussions between the disciples of the rival schools of Werner and Hutton, or, as they were called, the Neptunists and the Plutonists; the former maintaining that all the rocks, the trap included, were deposited from water, and the latter con-

tending that granite and the trap rocks were of igneous origin. For some time, therefore, Geology was regarded by most, even of the learned, as a science rather calculated to amuse speculative minds than to render any valuable service to mankind; while others, as in the days of Galileo with regard to Astronomy, assailed the geologists with the charge of presumption, and represented their discoveries as having a tendency to injure the cause of religion, by undermining the authority of the sacred writings. The more extended researches which the above rival opinions served to stimulate, not only corrected the errors of Werner, and set at rest the questions so long and fiercely agitated between rival geologists, but opened up such extensive views of beneficent design in the structure of the earth, as silenced all plausible objection to a more enlightened interpretation of the sacred records, in respect to the great work of creation; while the knowledge so obtained was productive of many and great advantages, by the light it threw upon agriculture, mining, and other economical arts which have most influence upon the welfare of mankind. The latter consideration renders the diffusion of a knowledge of Geology an almost indispensable ingredient in the education of youth, which it is the object of the present little

work to promote, and in which it has been attempted to embody the rudiments at least of the science, and as much of the details of British Geology as will, perhaps, be thought sufficient for the information of the generality of readers, and for laying the foundation of a more profound knowledge of the subject in minds disposed to more extensive acquirement.

In offering this brief compendium to the public, the writer, though for many years an attentive observer of the phenomena of Geology in most parts of the kingdom, freely acknowledges his obligations to the works of several of our most able geologists, whose united labours have done so much honour to British science in this yet new path of inquiry.

The small geological map at the commencement of the book is given for the purpose of affording the beginner greater facility in obtaining a correct general idea of the arrangement of the strata; but for a more particular and exact delineation, he is referred to the Geological Map of the United Kingdom, by Professor Phillips, published by the Committee at so moderate a price as to place it within the reach of every person desirous of

obtaining geological information. The engravings of fossils have, for greater convenience, been placed together at the end of the book, with the sectional Map of the Strata. In the Glossary will be found, not only an explanation of terms, but a description and analysis of many of the principal minerals.

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GEOLOGY, or, as the word implies, a discourse of the earth, in the widest sense of the term, would include a description of all the vast masses which compose the entire surface of the globe, as exhibited to our view in the distribution of oceans, seas, and lakes, continents and islands; the mountains, rocks, hills, and valleys, which diversify its surface; the materials of which they are composed; the natural or secondary causes by which they have assumed their present form and arrangement, and the changes which they are now

undergoing. It is not, however, intended in this little work to embrace so wide a field ; but, after some general, and, as we conceive, needful explanatory observations on the principal phenomena of geology, rather to confine our views to the rocks and strata of England, with some notice of those of Scotland and Ireland ; where the subjects treated of are more within the reach of observation, and the study of them calculated to interest the generality of English readers, and to lead to more practical and useful results. Occasional notice, however, will be taken of relative or corresponding features and phenomena of other countries, wherever such notice may be deemed expedient or useful in illustration of the main subject, or any of its particular parts.

It is almost needless to insist upon the benefits to be derived from a knowledge of geology to mankind. It enables us to understand the cause of the great diversity of soils which the surface of the earth presents ; the fertility of some, the barrenness of others, and the means which nature places at our disposal for their improvement ; while it facilitates the search for water-springs, and the drainage of land : it teaches us where to look for the depositions of mineral wealth with the greater probability of finding them ; the situation, particularly, of workable and profitable coal beds, of rock-salt, and brine springs ; of the strata which afford lime and the various and most valuable building stones, cements, brick and potters' clay, with other earthy materials used in the arts ; the rocks which yield iron, copper, tin, lead, zinc, and manganese ; all of which abound in our island, and, by the genius and industry of its in-

habitants, have been the means of raising it to its present preeminence of wealth and power among the nations of the earth.

England presents great advantages for the study of geology, as perhaps there is no country upon the face of the earth which affords, in an equal space, so great a number and so regular a sequence of strata of all ages, and so many well marked diversities of character; and it is perhaps partly owing to this circumstance, that our countrymen have made a more rapid progress in the science, and enriched it with larger contributions, than the people of any of the continental nations. Though the English philosophers were, indeed, not the first to take the field in the prosecution of this most interesting and important science, yet they have followed it up with unrivalled spirit and energy; and within little more than half a century, the subject has been illustrated by the genius and labours of many eminent geologists, of whom we may be justly proud when we can number amongst them, Hutton, Playfair, Smith, Sedgwick, Buckland, Conybeare, William Phillips, Lyell, Murchison, Macculloch, Mantell, John Phillips, Ansted, and many others, whose talents have enlarged the bounds of human knowledge in a new path of discovery, which approaches astronomy in the sublimity and interest of its objects, and is calculated to produce a more immediate and greater effect upon the welfare of mankind. One of the great benefits which have already attended the researches of geologists, and to which allusion has been made above, is the prevention of fruitless attempts in search of coal; for before they had ascertained the true position

amongst the strata of workable and profitable beds of this valuable material, large sums were spent in various parts of the kingdom, in localities where there was no chance of finding it. Practical miners, misled by what they considered as indications of coal, induced adventurers to sink a great amount of capital in the vain endeavour to find it; of which a remarkable instance occurred at Blackheath, where an enormous expense was incurred; a situation now known not to afford the slightest rational hope of success. Available beds of coal are now ascertained to be associated with certain well-known rocks (in England), and any search for it in situations remote from these, is sure to end in disappointment. As our knowledge of geology extends and becomes more generally diffused, there can be no doubt that greater certainty will attend all the operations of mining, as well for coals as other minerals, as the miner will be directed to their particular localities by more trustworthy guides and less fallible inductions.

Every step we make in this new path of discovery, opens more extended views and produces more exalted conceptions of the power, wisdom, and prescience of the great Author of nature, whether we consider the magnificence of the objects presented to the mind, or their admirable arrangement for beneficent and often very remote consequences. Astronomy presents us with objects upon so vast a scale, as to exceed our utmost powers of comprehension, and in contemplating them, the mind sinks under the oppression of "thoughts beyond the limits of our frame." Even amongst the most gifted, but few can avail themselves of the necessary means of prosecuting this

branch of knowledge with any tolerable success, by penetrating the awful depths of space which separate us from even the nearest objects which attract our attention; while the subjects which geology offers to our attention and rational inquiry, are for the most part within our reach, and may be subjected to close and repeated examination, requiring neither expensive apparatus, nor any great effort of intellect, but yet presenting to the mind an almost infinite variety of phenomena, upon a scale calculated to awaken the most powerful emotions of astonishment and admiration, and to excite the strongest desire to investigate them. Indeed, those who, prompted by a healthful and rational curiosity, consult the great volume of nature, which the Creator has laid open to our inspection, must prepare their minds for the most astounding announcements, as every page is replete with wonders "surpassing fable and yet true," of which geology alone affords innumerable instances. In the history of human events, we read the occurrences of a few thousand years; geology reveals the records of a long succession of ages, which it has pleased the Divine Author of nature should precede the creation of man; during which, operations were going on which effected great changes in the physical condition of our planet, and in both vegetable and animal existence; changes which there can be no doubt, in the prescience of the Divine mind, were providentially pre-ordained for the existence and accommodation of the present inhabitants of the earth, and especially for man, the last and noblest work of creative wisdom. We are indeed permitted so far to penetrate into the scheme of the beneficent prescience

of the great Author of our being, and of all that we see around us, as to presume that certain productions and events of very remote geological periods had reference to the appearance of man upon the earth, which otherwise, according to our most rational conclusions, would not have been a fit habitation for him. We allude more particularly to two very remarkable instances: the formation of metallic veins in some of the oldest rocks, and that vast accumulation of vegetable remains which compose our coal beds. No rational mind can doubt that these were designed and prepared for the use of man, as means of accommodation and physical power, and for the increase and development of his intellectual faculties.

The production of these substances so far back in the depths of time, and their admirable adaptation to the purposes of human life, impress the mind with a deep conviction that the progressive changes which have produced and modified the strata of the earth, and out of seeming confusion brought about the present beautiful order of things, have been constantly under one and the same controlling providential Power, to whose all-seeing eye there is no remoteness either of space or time. The progressive works of creation, of which geology discloses innumerable monuments in the crust of the earth, afford us wider and wider views of beneficent design operating through immense periods of the past, peopling the land and filling the waters with successive races of animals, capable of enjoying, and which no doubt fully enjoyed, their transitory existence.

In taking this extended view of creative *beneficence*, we do not in the slightest degree impugn

the veracity of the sacred writings, when interpreted by the aid of that knowledge which the Divine Author has imparted to man, through the instrumentality of his own researches and observation; and that such views are not incompatible with Divine Revelation, we have the highest living authority in the writings of the present very learned and pious Archbishop of Canterbury, who in his admirable work upon the Records of Creation, thus expresses himself:—"Any curious information on the structure of the earth, ought not to be expected by any one acquainted with the general character of the Mosaic records. There is nothing in them to gratify the curiosity or to repress the researches of mankind, when brought, in the progress of cultivation, to calculate the motions of the heavenly bodies, or speculate on the formation of the globe. The expressions are evidently accommodated to the first and familiar notions derived from the sensible appearances of the earth and the heavens; and the absurdity of supposing that the literal interpretation of terms in Scripture ought to interfere with philosophical inquiry, would have been as generally forgotten as renounced, if the oppressors of Galileo had not found a place in history. The concessions, if they may be so called, of believers in Revelation on this point, have been amply remunerated by the sublime discoveries as to the prospective wisdom of the Creator, which have been gradually unfolded by the progressive improvements in astronomical knowledge. We may trust with the same confidence as to any future results from geology, if the science should ever find its Newton, and break through the various

obstacles peculiar to the study, which have hitherto precluded any general solution of its numerous and opposite phenomena. All that I am concerned in establishing is, the unreasonableness of supposing that geological discoveries, so far as they have hitherto proceeded, are hostile to the Mosaic account of the creation. No rational naturalist would attempt to describe, either from the brief narration in Genesis or otherwise, the process by which our system was brought from confusion into a regular and habitable state. No rational theologian will direct his hostility against any theory which, acknowledging the agency of the Creator, only attempts to point out the secondary instruments he has employed. According to the sacred history, we are bound to admit that only one general destruction or revolution of the globe has taken place since the period of the creation of man, which Moses records, and of which Adam and Eve were the first inhabitants. *But we are not called upon to deny the possible existence of previous worlds, from the wreck of which our globe was organized; and the ruins of which are now furnishing matter for our curiosity.* The belief of their existence is, indeed, consistent with rational probability, and somewhat confirmed by the discoveries of astronomy and the plurality of worlds."

It must be evident to the most pious mind, that the sacred Scriptures were not intended to be the vehicle of physical knowledge, or to supersede the active powers of the human mind, when in after times its attention might be directed to the sublime and beautiful phenomena of creation, and to the investigation of those laws by the agency

of which the great Creator has wrought and continues to work in their production, and of which we have of late witnessed such astonishing revelations in astronomy, geology, and chemistry. Is it not rather perfectly consistent with our ideas of the wisdom and beneficence of the great Author of nature, that the knowledge of his works should be progressively achieved by means of those powers which he has conferred upon man, the exercise of which is attended with so much rational pleasure, and is productive of such continually increasing benefit and sources of enjoyment? Thus much it has been thought necessary to premise, in order to meet any objection to the high antiquity of the mere mass of our globe which geological phenomena disclose, arising from an apprehension that it impugns the veracity of that Divine Revelation, which was imparted to man for far other and higher purposes than that of affording a knowledge of physical phenomena.

When we contemplate the magnificent spectacle which the surface of the earth exhibits to our view—its investing mantles of air and water, its continents and islands, diversified with mountains, hills, rocks, valleys and plains, covered for the most part with an abundant and beautiful vegetation, affording support and the means of enjoyment to an almost endless variety of living beings, from the enormous whale and bulky elephant to innumerable tribes of insects and animalculæ discoverable only by the most powerful glasses, which appear to succeed each other in a constant order of successive generations from the earliest period of recorded time—we may well

suppose that we behold in the vast inanimate masses the character of unchanging stability and duration, and in their living inhabitants the limits on our globe of creative wisdom and beneficence. These impressions will, however, soon be removed by an attentive and searching inspection; for when we penetrate beneath the present life-sustaining surface of the strata, we are soon convinced that what we had hitherto regarded as an unchangeable condition of things, presents only the last chapter of a most eventful history; and that these strata of which the surface of the earth is principally composed, are so many monuments of its past history, on which are recorded in unmistakeable characters successive changes of the relative position of land and sea, and corresponding mutations in living forms which now no longer exist, whose remains are entombed in the strata, and are so numerous as to constitute a very large portion, and, in some instances, almost their entire mass. From these remains we learn that our globe has been peopled at very remote periods by numerous races of animals, and covered by plants, differing widely from those which now occupy its surface; that each of these races, after continuing for a while, has gradually disappeared, and given place to others. The greater part of those animals whose remains have been thus handed down to us, were shell-fish and other inhabitants of the waters, where, from all appearances, they must have lived, died, and been covered up, as the greater portion of them have sustained no mechanical injury, and retain their finest and most delicate forms. As they are now found imbedded in extensive strata of dry land,

not only near the sea, but in the remote inland parts of continents, it is most evident that the sea and land must have changed places, that the bottom of ancient seas must have risen up and become dry land; and in many instances so great is the extent to which this has taken place, that rocks containing the fossil remains of sea animals are found on or near the summits of very lofty mountains, far above the ordinary range of the clouds. On the Andes of South America they have been discovered 14,000 feet, and in the Himalaya mountains of India 16,000 feet, above the level of the sea.

It is with difficulty that we bring our minds to believe that the vast masses which compose the present dry land, and the lofty summits of mountains, have undergone such changes of level as that above mentioned; but, however contrary it may be to our preconceived notions of the fixity of these masses, it is impossible, after an examination of the substances of which they are principally composed, that we can arrive at any other conclusion, or deny that in many instances there have been alternate changes from land to sea and sea to land. Every part of the surface of the earth hitherto examined exhibits the same indications of the present dry land having risen from beneath the surface of the sea, the general character of which is, that it consists of immense layers or strata evidently deposited by water, some of them of enormous thickness, and a large portion of them containing an immense quantity of fossils, or the remains of animal and vegetable life, chiefly the former. These strata, for the most part, lie one over the other in a certain general order of

superposition, and with various degrees of inclination, from a nearly horizontal to almost a vertical position, and all repose upon unstratified and crystalline rocks of unknown depth, which not only underlie the stratified masses, but also rise above them, and generally form the central and highest ridges of the loftiest mountain ranges upon the face of the globe.

That the stratified rocks, from the lowest to the uppermost, have been gradually deposited by water, in a horizontal position, there can be no room for doubt, as each stratum is composed of an immense number of thin layers, exactly resembling in this respect the deposit which at present takes place under our eyes in ponds and lakes of the sedimentary matter of turbid water which flows into them. We have existing examples also upon the largest scale of the manner in which the strata were formed, in the immense quantity of sedimentary matter brought down by large rivers and deposited in the sea at their mouths, and which is known to be hardening into rocks, and inclosing shell-fish beneath the waters. These rivers, also, carry down to the sea the plants and animals of the land through which they flow; these, sinking to the bottom, are covered up by successive deposits: this explains that mixture of the productions of the sea and land which many of the strata exhibit. The strata formed in ancient times by such means and by the transporting power of the currents of the ocean, were subsequently consolidated into rocks or rocky masses of greater or less degrees of hardness, and, gradually raised above the waters by the ascending motion of the *unstratified* rocks beneath them, now form the larger

portion of the present dry land, as before noticed. In many cases it may be seen that the earlier formed, or lower strata, began to rise before those above them were deposited, as the latter are frequently found resting unconformably, or with a different degree of inclination, upon those beneath them, as represented in the following section.



The above may be considered as affording a rude approximation to the character of the stratification of a mountain district in which the older stratified rocks, 2, 3, 4, are seen resting in a highly inclined position upon the unstratified central mass 1, and the more recent strata 5 lying in an unconformable and nearly horizontal position upon the sloping sides, and perhaps forming the general level of the country. Such is the actual character of many mountain ranges; and it must be evident from such a relative position of the successive strata, that the central portion had begun to rise and might have been already above the surface of the sea, before the deposition of the more recent and horizontal strata. If all the stratified rocks had been formed before the central mass rose from beneath, they would have all exhibited the same, or nearly the same, highly inclined position, and portions of them would have been carried up upon the summit, or at least would have occupied a very elevated position. This is not unfrequently

the case, and rocks of comparatively recent age are seen to occupy the highest places on some of the loftiest ridges in Europe, as the Tyrolese Alps and the Pyrenees.

The unstratified rocks, which underlie and frequently rise from beneath all the others, are undoubtedly of igneous origin; that is, they owe their present condition and mineral character to the action of heat upon their materials, which must have assumed their present form when in a molten state. Granite is the principal of these, and forms those central masses of lofty mountains upon which the stratified or sedimentary rocks rest. The other igneous rocks, which differ from granite more in external appearance or the arrangement of their minerals than in their real chemical or elementary composition, are called *trap rocks*; these, together with granite, have penetrated, fractured and upheaved the incumbent stratified rocks, and by this action have produced all the mountain ranges and most of the lesser inequalities which diversify the surface of the earth. For the most part, this action of the molten rocks has taken place at immense depths beneath both the dry land and the bed of the sea; and it is from this circumstance, and from their original molten condition, that they are frequently called by geologists *plutonic rocks*. In the derangement of the strata which compose the greater part of the slopes and lower ridges of the enormous masses of mountain ranges, we witness the most striking effect of the power by which these rocks are in some situations forced upwards; but these are only more conspicuous instances of the effect of the subterranean forces, which have raised all

the present dry land from the depth of the sea, and produced by their partial action at particular points those inequalities which its surface exhibits. If the incumbent strata were partially upraised when beneath the water, the retiring currents would furrow the surfaces with valleys; and if much dislocated, those deeper valleys would be produced with corresponding strata on either side, which are so frequently seen, and which are strikingly exhibited in the valley of Bath, though the igneous rocks have not made their way to the surface, the cause of the disturbance being there only indicated by the hot springs which rise in the bottom of the valley.

The present signs of these upheaving subterraneous forces are exhibited in earthquakes, which occasionally not only fracture and break up the strata on the dry land, but agitate them beneath the depths of the sea, the effect of which is felt over large portions of the globe at the same time. Even within a few years of the present time, these forces have produced a permanent elevation of the land of several feet over a space of 100,000 square miles of country on the coast and inland parts of Chili in South America, and another of great extent on the banks of the Indus. Numerous instances of the elevation of the land upon a more limited scale have been experienced and recorded both in ancient and modern times; but when we consider the comparatively small portion of the earth which is occupied by civilized man, it is very probable that many extensive movements of this kind have taken place which have escaped attention, or have not been recorded. Existing and active volcanoes will afford us some faint idea

of the force with which the molten matter which formed the trap rocks was impelled upwards and by which it penetrated and upraised the incumbent strata. In these volcanoes, the molten lava rises from immense depths beneath the base of the mountains to their summits, or is forced out through their sides. The streams of lava which pour forth from these volcanoes consist of nearly the same materials, and are of the same chemical composition, as those of the trap rocks; and the difference observable in their external appearance and mineral arrangement, there is substantial ground for believing, is owing to the different circumstances under which they have been consolidated; the trap rocks having cooled slowly under enormous pressure either of incumbent strata or of the ocean, and the lavas more rapidly on the surface. The lavas which are called *volcanic rocks* may be considered as *trap rocks*, so to speak, which have found their way to the surface beneath the pressure of the atmosphere only; and their upward movements, and the force with which they are ejected, as a visible type of the power exerted in the invisible depths of the earth, the former effects of which are exhibited in the elevation of the strata, and the inequalities thereby produced upon the surface.

There are three circumstances which confirm geologists in the opinion that the unstratified rocks were originally like lava in a molten or semifluid state: first, their crystalline structure; secondly, the manner in which they have penetrated and fissured other rocks both in a vertical and horizontal direction, in a way which they could *not* otherwise have done; and, lastly, the chemical

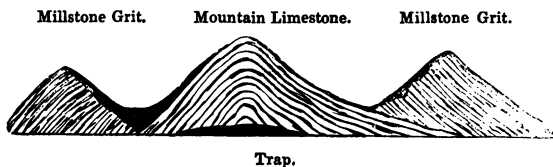
changes they have produced upon the strata they have so invaded, by converting earthy and shaly beds into granular masses of hard rock, common limestone into crystalline marble, and coal into coke, the known effect of heat upon such substances out of contact of air and under great pressure. The strata so altered by the contact of heated matter have obtained the name of *metamorphic rocks*. The annexed sketch will afford some idea of the manner in which granitic veins are observed to penetrate older rocks of the same kind, and those and other trap veins fissure vertically and horizontally the stratified rocks, and sometimes overlie them.



On the right-hand side a rock of granite and the highly inclined strata resting upon it are penetrated by granite veins; and on the left other trap veins rise through the more horizontal strata, penetrating between and overlying them. Instances of the penetration of granite rocks by veins of newer granite occur in many parts of Scotland, and of the intrusion of trap rocks or dikes in many parts of England, where they frequently embarrass and interrupt the operations of the miner, both by their extreme hardness and the displacement of the strata which they pervade. These trap rocks sometimes assume the appearance of walls when

they rise to the surface, of which there is a remarkable instance in the north of England, where a wall or dike of this kind, of considerable breadth, extends from near Whitby to the westward through several successive strata, including the coal measures. Other dikes occur farther north, traversing the coal measures and mountain limestone; and trap rocks occur abundantly in the coal-fields and on the western shores of Scotland. Those trap rocks, called basaltic, sometimes take the form of columns, as at the Salisbury Crags, Edinburgh, Fingal's Cave on the Island of Staffa, and the Giants' Causeway on the north shore of Ireland.

The effects of trap rocks in lifting and penetrating the regular strata are remarkably displayed in the district round Matlock in Derbyshire, particularly at Crich-hill, of which a particular description is given by Dr. Mantell. The limestone strata, of which the hill consists, have been lifted up into a dome-like shape, and exceedingly shattered, and the sandstone strata which overlaid the limestone removed, as the rocks on either side clearly indicate, and as is represented in the section beneath:—



The trap rock of this district is called Amygdaloid, or Toadstone, from the peculiar spotted character it exhibits.

The instances given above of the intrusion of igneous rocks into the incumbent strata, and the evident effect they have produced in their elevation and disturbance in almost innumerable observed instances, are sufficient to warrant the conclusion, that by such means were effected the general upward movement of the strata which now form the dry land, and those great inequalities which constitute mountain ranges in almost every part of the earth.

The phenomena of trap and intrusive rocks may be well studied in the coast sections of the Isle of Arran, of which and the adjoining islands detailed descriptions will be found in Dr. Macculloch's *Geology of the Western Islands*.

CHAPTER II.

General view of the Stratified Rocks of England, Wales, and Scotland—Their elevation and dislocations, and the appearance their surfaces exhibit—Their different character, and the means by which they are distinguished—Fossiliferous Rocks—Dr. William Smith, his great Geological discovery—The constancy of the Fossil character of Rocks—The proofs they exhibit of successive changes of land and sea over the same spot—Fossil Remains of Land Animals and those of Trees, Plants, and Seeds—Remains of various Animals found in Kirkdale and other Caverns, and in diluvial Gravels in Siberia and North and South America—Adaptation of the present condition of the Earth to the existence of its Inhabitants—Changes now in progress—Formation of Coral Reefs and Islands—Submarine Mountains, gradual shoaling of the Baltic Sea, raised Beaches, and submerged Forests—The wearing down of Continents, and the production of Deltas and Submarine Deposits, and the enormous quantity of Silty matter transported by great Rivers, with the effects produced in the progress of time within the notice of history, in the recession of the Sea and the filling up of Lakes—Observations of Ancient Philosophers on Geological changes—Arabian Fable.

WHEN we travel over the lower, and generally fertile tracts of any country towards the elevated lands or mountains,—for instance, if we start from London and proceed in a north-west direction,—we witness the occurrence at frequent but varying intervals of soils of the most opposite character, but principally consisting of clays, sands, chalk, and imperfect limestones, succeeding each other without any apparent regularity, but rather impressing the mind with the idea of confusion and disorder. By a more attentive observation, however, we shall discover that this seeming confusion is capable of being reduced to some degree of order; and that the variation of the soils we have noticed is owing to their resting upon, and form-

ing the upper portion of clayey, or sandy beds or strata, alternating with others of limestone, and as we proceed farther westward, of slaty and crystalline rocks (all of which are called rocks by geologists), which lie over one another, or crop out, as it is called, one from beneath the other, somewhat after the manner of a pack of cards partially spread upon a table, or the over-lapping of tiles upon the roof of a house, and discovering a greater or less extent of their surface; sometimes a very limited portion, but frequently extending many miles, and occupying wide districts of different degrees of elevation: of this some idea may be formed from the following section:—



These strata are of various thickness, and over a large portion of the kingdom of low inclination, cropping out and presenting their edges to the north-west. In the opposite direction—that is, from north-east to south-west—many of these strata range with an irregular line nearly across the kingdom, presenting the appearance of bands of different degrees both of breadth and length. Their inclination is by no means constant, as in many instances they have suffered great displacement, and those rocks which are the lowest in order, or the earliest formed, often become highly inclined, and rise with steep sides into bold hills and mountain ridges, as in Wales and the counties of the extreme north-west of England and the

greater part of Scotland. The derangements which the strata have undergone at various periods in the course of their progressive deposition, are often strikingly exhibited by one rock of low inclination resting unconformably upon the up-raised and steep surface of that beneath it, from which it is evident that the lower stratum had been consolidated and subsequently raised before the other was deposited upon it. In numerous instances the disrupted strata beneath have their edges covered up by others which have been formed over them. The following section will exhibit the nature of these derangements and overlyings:—



The appearance which the several strata present at their outcrop will depend upon the materials of which they are composed: if they consist of hard and compact rocks, their edges will appear bold and abrupt, as in the limestones and the slates; if the materials are less consolidated, as in the softer sandstones, their terminations will be more or less rounded; and those strata which are composed of soft and loose materials, such as sands and clays, will gradually blend with the stratum beneath, without presenting any marked elevation at their extremities, as represented in the outcrop of the strata in section, p. 21.

The several strata are distinguished from each other by three distinct indications, viz.—their *mineral* character, their relative position or order

of superposition, and lastly and chiefly, by the fossil or organic remains which they contain. The first of these, taken by itself, cannot always be relied upon, as rocks or strata very remote from each other in the order of their superposition very much resemble each other in their mineral constitution; and therefore, the two others taken together afford the only certain means of determining the geological position of any particular stratum in the general series, or in other words, its relative age. The very oldest of the stratified rocks are those which occupy the lowest position in the order of succession, but these are generally so marked by their mineral character, as to render it easy to determine their geological position by a hand specimen, as they consist of dark slates, or still harder crystalline rocks. Moreover, they are generally highly inclined, and often form the entire mass of lofty mountains, as in North and South Wales, Westmoreland, Cumberland, and very generally in Scotland. To such rocks succeed in the ascending order that extensive series of strata which have received the general name of fossiliferous, from their containing imbedded fossils, or petrified organic remains.

About fifty years ago, the late Dr. William Smith, who has not improperly been called the father of English geology, made the discovery, after an extensive series of observations and a close examination of the strata in every part of the kingdom, that the fossils of one stratum differed materially from those of another; that the difference became the more marked in those which were widely separated; and that the fossils of those the most remote from each other were altogether of a

different character ; that any particular fossil shell which abounded most in one rock, became less numerous or disappeared in the one above it, and was replaced by another species, which in its turn suddenly or gradually gave place to others in the ascending series of rocks. This prevalence of particular fossils in each rock was found to be so constant, as to serve as an indication and means of determining the position of any one in the series, whatever might be its mineral composition, as rocks so characterised were found never to change their relative position with respect to each other ; that is, a rock containing certain fossils has never been found above another in one place and beneath it in others. The successive changes in the fossil remains have continued through all the strata in the ascending order, to the last or newest of those which now form the dry land ; these so nearly resemble the living inhabitants of the adjoining seas as to be scarcely distinguishable from them, and are for the most part identical with them.

The fossils found imbedded in the strata are not confined to shells, but comprise those of fish, enormous reptiles, land animals of various kinds, birds, and even insects, with a great variety of plants, and in some instances seeds, all of which are now extinct. From the peculiar position of many of the productions of the land, it is evident that in some localities the land and sea have changed places more than once, as the remains of mammiferous or milk-giving land animals are found imbedded in strata formed by fresh water, as is manifested by the accompanying shells, covered by thick deposits containing only those of

marine origin; while stumps of trees are discovered still rooted in the soil, and covered by deposits both of fresh and salt water of many hundred feet thick. The last fossil remains of land animals are found in superficial gravels in most parts of the world, and also imbedded in the silty deposits of caverns, as well as in the marls at the bottom of peat bogs. These are mostly of extinct races, but sometimes associated with many which cannot be distinguished from existing species. Such fossil remains are found abundantly both in the old and new continents, and in climates not now adapted to their habitation. In Siberia, on the borders of the frozen ocean, the remains of elephants are so numerous and so well preserved, as to furnish an inexhaustible supply of ivory as an article of commerce; and in one instance, an entire elephant was discovered imbedded in ice on the banks of the river Lena, so perfectly preserved that the dogs and wolves devoured the flesh; and of such dimensions, that it was with difficulty that eleven men removed the skin to a boat. The fossil remains found in gravels, consist of the above gigantic elephant; the mastodon, a similar animal; the megalonyx and megatherium, two enormous extinct animals, found in the United States and South America; the hippopotamus; rhinoceroses of four kinds; gigantic tapirs; stags, oxen, aurochs, bears, horses, lions, tigers, hyenas, dogs, cats, &c.

Caverns in limestone rocks in various parts of the world, are remarkable for containing the imbedded bones of a great variety of animals, and in great abundance. In the Kirkdale Cavern in Yorkshire, Professor Buckland discovered very

numerous remains of large hyenas, associated with bones, more or less fractured, of species of tiger, elephant, rhinoceros, hippopotamus, horse, deer, ox, wolf, bear, fox, weasel, hare, mouse, water rat, and fragments of skeletons of ravens, pigeons, larks, and ducks. From the great number of the remains of hyenas, Professor Buckland inferred, that the cave was the resort and habitation of these beasts of prey; and that most of the remains were those of animals whose fragments had been carried in by them, as many of the larger bones exhibit marks of having been gnawed. The larger animals might sometimes have fallen a prey to these ferocious beasts, but the smaller ones, especially the birds, were probably drifted in by the waters which deposited the silt in which they were imbedded. Similar remains are found in a cave near Torquay; in Oreston Cave near Plymouth; in Banwell Cave, in the western district of the Mendip Hills, Somerset; and in Goats Hole, and Paveland Cave, near Swansea.

Bone breccias (fragments of bones united by stony matter) are found in numerous parts of the shores of the Mediterranean, at Gibraltar, Cette, Nice, &c.; most of these bones, like those before mentioned, belong to extinct species—though in certain places they are associated with those of animals now in existence; but the bones of man have never been found in these deposits. The latter have, indeed, been discovered in sandstones which are known to be of recent origin, of which a specimen exists in the British Museum, brought from the Island of Guadaloupe in the West Indies.

The animal remains found in the diluvial beds or gravels, or covered up with silt in caverns in so

many parts of the world, appear to have been for the most part deposited and inhumed by one or more of those great catastrophes which have from time to time effected great changes in the form of the surface of the earth, and, probably, alterations of climate. That great changes of climate, however produced, have taken place in northern latitudes, is most evident, from the character of the organic remains contained in the strata from the coal measures upwards to those superficial deposits which we have just mentioned, as they belonged to animals and plants which could have existed only in a climate of high temperature, at least equal to that of our present torrid zone. The perfect condition of most of them indicates that they could not have been transported from great distances, but must have lived and died on or near the spot where their remains are covered up and are now discovered. That the change of climate in one instance, at least, was both great and sudden, must be inferred from the immense quantity of the fossil remains of elephants or mammoths found in the frozen plains of Siberia; and particularly from the almost perfect condition of even the flesh and skin of that above mentioned, which was frozen up in the ice on the banks of the Lena, and thus wonderfully preserved from putrefaction for perhaps thousands of years. At a temperature below the freezing point, and excluded, at the same time, from the air, the most frail and delicate animal and vegetable substances are as imperishable as the hardest rock.

Such is the general character of the structure and arrangement of the rocks or strata which compose the mass, and form the surface of the

visible crust of the earth ; and such the creative and sustaining beneficence they exhibit in the remains of animals which they once supported.

Though the great inequalities which the surface of our globe everywhere exhibits, indicate the action of upheaving, and what we might at first sight regard as the effect of the wild and destructive forces of subterranean elements, yet we recognise in the actual arrangements, which are the result of that seeming destruction, the work of profound wisdom and beneficent design ; for, all things considered, it is impossible to conceive a world whose physical conformation would be better adapted to its present inhabitants, and especially to man, who alone has been gifted with powers to discern, and a tongue to pronounce, that the hand that made it was Divine ; and who, viewing the sublime and beautiful spectacle it presents, may well exclaim—
“ How wonderful are thy works ! in wisdom hast thou made them all ; the earth is full of thy goodness ;” or in the almost divine language of our great poet :—

“ These are thy glorious works, Parent of good,
Almighty ! Thine this universal frame,
Thus wondrous fair, Thyself how wondrous then ;
Unspeakable ! who sit'st above these heavens,
To us invisible, or dimly seen
In these thy lowest works, yet these declare
Thy goodness beyond thought and power divine.”

Scenes which have the power to inspire the mind of man with such exalted sentiments as these, which every reflecting mind must feel, though few can express so happily, cannot have resulted from the chance work of uncontrolled elementary disturbance, but must be attributed alone to a Divine

original prescience extending through the abyss of time, and with a power invisible working out his beneficent designs by the instrumentality of visible agents—the strife of elementary matter, the volcano, and the earthquake, the lightning, the storm, and the ever-moving waters, that wait upon his pleasure and do his bidding. The inspired writings everywhere abound with passages expressive of the continual superintendence of the infinite and all-wise Creator; and the uninspired reason of man, contemplating the magnificence, beauty and harmony which everywhere prevail, can arrive at no other conclusion.

Had the ponderous materials of which our planet is composed settled down, or occupied places according to their respective weights, and the law of gravity prevailed undisturbed by antagonistic upheaving forces, the whole face of the globe must have been covered by water, as the present dry land occupies little more than one-fourth of that space; in which case neither vegetables nor animals, such as now cover and inhabit the face of the earth, could have had any existence; the sun would rise and set upon a dreary waste of waters and its unconscious inhabitants, if, indeed, any could have existed in such a condition of the globe. How different is the scene which the actual state of things presents! Those subterranean forces which have raised our continents and islands, have, by acting with greater energy in particular parts, variously fractured and upheaved certain portions of the enormous mass, and produced all that variety of form which now diversifies the surface with mountain, hill, and valley, by which the clouds are condensed in rain, the streams directed

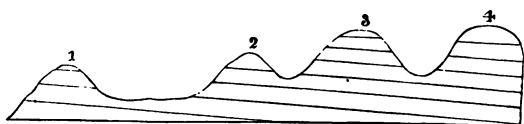
in their course, and the whole rendered a fit place of habitation for the beings for which it was intended.

Through what depths of time such changes have been in progress will, perhaps, never be revealed by the researches of man; but observed facts afford us the strongest and most convincing proofs, that by such vast movements the present relative positions of land and sea have been effected, and all the existing beautiful and beneficial arrangement produced. Without the inequalities or partial elevations of hills and mountains, which condense the vapours of the atmosphere, the earth had been destitute of fresh water, and neither springs, waterfalls, nor rivers would have enlivened and fertilised its surface. Those subterranean forces which caused the elevation of mountain masses, also produced fissures, the receptacles of metallic ores, which would not have been available to man but for the continuance of subsequent upward movements which have placed them within his reach. The veins of metals pervading rocks, which, according to all appearances, must have been formed beneath the depths of the sea, are, in numerous instances, in both the old and new continents, raised many thousand feet above its surface, and thus rendered accessible. Those vast masses of coal which are the principal source of the wealth of England, and are so very valuable to mankind wherever they are found, have evidently been formed from accumulations of vegetable matter deposited at the bottom of seas and lakes, and subsequently covered up to a great depth with sand and other sedimentary matter, which afterwards hardened into sandstone and

shaly beds, which by their pressure have caused its consolidation into those firm and almost rocky masses which it everywhere exhibits. These beds of coal, which are of various thickness, from a few inches to thirty feet, are likewise separated by, or alternate with, beds of sandstone, shale, and sometimes limestone, forming a mass of deposition of many hundred feet deep. Over all these have been superimposed numerous other strata of great thickness, containing no coal. From the position thus occupied by the coal measures, as the coal-bearing strata are called, beneath the sea, and overlaid by other strata, they must have remained for ever out of the reach of human industry. But what man could not effect has been performed for him by the agency of those subterranean forces before mentioned, which have raised these from their deep-sunk position beneath the bed of the waters, to often many hundred feet above their surface, and thus rendered them an available means of promoting the comfort, the arts, and the civilization of mankind.

Not only have the strata been upraised above the waters, but, during their elevation, and probably afterwards by transient inundation, their surfaces have been deeply furrowed or denuded by the force of the currents which such movements must have necessarily produced, as is evinced by the deep valleys which the face of almost every country exhibits. Some of these, in the uplands and interior districts, are no longer the channels of water; while most of them are traversed by streams and rivers, still indicating the course of those mighty retiring torrents which scooped out the deep and wide valleys, that now serve as the

natural drainage of the country. Such denuding forces have not only thus beneficially modified the surface of the earth, by rendering it a more healthful and suitable place of habitation for man and the inferior animals; but, by dividing the strata in so many different places, by removing some and exposing the edges of others along the bottoms and sides of the valleys thus formed, have rendered these materials easily accessible for economical purposes, and facilitated the operations of mining by rendering drainage less expensive and laborious. The section beneath, cutting across the line of valleys, will sufficiently explain what is here meant; that is, the manner in which these valleys of denudation expose the strata of which their sides and bottoms are formed.



Here we have the valleys (and it is a common occurrence) cutting through the inclined strata, and exposing their edges along their flanks, and laying bare the lowest in each, by which condition it will be at once apparent that the materials of each stratum so cut through and exposed are rendered more easily accessible. The wide valley between 1 and 2 has left what is called an outlier, No. 1, the upper part of which consists of the same strata as crop out in the valley and form part of the side of the hill, No. 2; while some of the strata of No. 4 crop out in the respective valleys, and form the upper portions of Nos. 3 and 2.

When such appearances occur in nature, there can be no question that the strata which crop out along the sides of such valleys were once continuous across the space those valleys occupy; and this is, perhaps, nowhere more remarkable than in the deep valley through which the Avon flows as it enters Somerset above Bath and along the valley below it. Here the edges of the corresponding strata are seen on either side of the great valley, and also in the minor valleys which open into it. The upper stratum, the great oolite or Bath building-stone, forms the small and nearly level plains on the summits of the hills; while a distant outlier, part of the same mass of oolite formation, appears at Dundry Hill near Bristol.

In noticing the beneficial effect of the disturbances the strata have undergone, we must not omit to draw attention to the present distribution of land and sea, which, in conjunction with mountainous elevations, exercises so powerful an influence on the climate of the several parts of the earth's surface, and affords such facility of communication between the most distant nations, as well as the convenience to commerce in deeply indented shores, harbours and tideways; in all which may be traced an admirable and ever-necessary adaptation of the actual state of the earth to the nature and wants of its present inhabitants, and especially of man. It is highly probable that any material change, either in the elevation of the several parts of the earth's surface, or a widely different distribution of land and sea, would be incompatible with the existence of many or most of the living beings which now inhabit both the land and water; and there is good ground

for supposing that the changes which our planet has evidently undergone in this respect have been the providential means of effecting those changes in animal and vegetable existence which the organic remains of successive races contained in the strata indicate to have taken place. There can be no question that the existence of an arid sandy desert, extending with little interruption from the Arabian Sea on the east, over Arabia and the great Sahara of northern Africa to the Atlantic, must have a material effect upon the climate of Europe, from the intense heat produced by a vertical sun upon a soil destitute of herbage, and fully exposed to its action. The heated air which ascends from these deserts, flowing to the north, and blending with the westerly winds which generally prevail in the higher latitudes of Europe, keeps up a higher temperature than would otherwise exist, more especially over the western part of the continent. That great current of the Atlantic, called the Gulf Stream, crossing from the African shores to the Gulf of Mexico, is reflected by the isthmus which unites North and South America, and flows through the Straits of Florida at a temperature of 80° Fahr. and diffusing its warmth over a wide expanse of the North Atlantic, produces a very decided effect in the temperature of its waters in very high latitudes, which, aided by the westerly winds, tempers the climate over the whole of western Europe, and must have an important effect upon the welfare of its inhabitants and the nature of its productions. If the space now occupied by the sands of Arabia and Africa had been open sea, and the Gulf of Mexico had communicated with the Pacific by a

wide opening to admit of the whole stream to pass through it, there can be no doubt but the climate of western Europe would have been very much colder than it is at present, and would have more nearly resembled that of the eastern coast of Asia in corresponding latitudes, so remarkable for the excessive rigour of its winters and the limited scale of its productions. From the effect produced upon the climate of Europe by the two causes above stated, it is easy to conceive what would be the consequence of a very different arrangement of land and sea from that which at present exists. If, for instance, nearly the whole of the space between the tropics were occupied by land, and there were open sea to the north and south, the heat produced by the action of the sun on so great an extent of equatorial land, and the consequent flow of heated water and warm wind towards either pole, would banish ice from the earth, and produce a comparatively warm climate in the highest latitudes. If, on the other hand, the equatorial region were entirely open sea, and the land accumulated round the poles, from the little effect of the sun in heating water, the opposite extreme of temperature would prevail, and the land would, in all probability, be rendered sterile by the rigour of a perpetual winter. In either case it must be obvious that the earth would become an unsuitable abode for the greater part of its present inhabitants. Changes of a minor degree in the relative position of sea and land might have attended, or been accommodated to, the existence of former races of animal and vegetable productions on our globe; for as we discover that all the works of creation which fall more within

the reach of our investigation manifest an admirable adaptation of means to an end, we are bound to believe that any former relative position of sea and land and that which at present exists were not the results of mere chance, but were brought about by appointed means under the direction and control of a profound and unerring wisdom.

In the works of creation progress is everywhere visible; and those causes which at very remote periods have effected changes in the relative position of land and sea, are still constantly in operation. Over wide portions of the tropical seas, and more especially in the great Pacific ocean, extensive reefs of coral are in the progress of formation, the magnitude of which (for many of them are several hundred miles in extent) is the more astonishing when we consider the minuteness of the animalcules by which such enormous masses of rock are raised. These coral rocks form numerous islands in the Pacific, some of them just appearing above the water, and others very considerably raised. Those in the mid ocean are evidently based upon the summits of submarine mountains; and as the operations of the Zoophytes, as they are called, must cease when they can no longer be overflowed by the water, it must be evident, that when the rocks are so elevated as to form high and dry land covered with vegetation far above the level of the sea, they could only have attained that elevation by the rising of the foundation upon which they rest. Mr. Darwin, to whom geology is very much indebted, has given a very particular and interesting account of these submarine formations, *and the gradual progress they are making to form*

islands and reefs, as well as of the proofs afforded of the elevation of some and the subsidence of others. The movement of such enormous masses as those which compose submarine mountains, proceeding, as it were, under our eyes and observation, and over such extensive areas, may afford us some idea of the way in which whole continents have been gradually raised above the waters which evidently once covered them; and how others may have disappeared which afforded the materials for those which now constitute the dry land, which often presents in inland situations lofty ridges of rocks produced by the same means as those we have just mentioned. The present continents and larger islands also exhibit proofs of similar gradual changes, of comparatively recent elevation and depression, in what are called raised beaches and submarine forests. It had long been a prevailing opinion amongst Swedish philosophers, that the bottom of the Baltic Sea was slowly rising, and the water consequently becoming shallower from century to century. Sir Charles Lyell states in his admirable work upon the principles of geology, that "the attention excited by the subject in the early part of the last century induced many of the scientific men of Sweden to determine by a series of observations the mean height of the waters of the Baltic; and under their direction, lines representing the true elevation were chiselled out upon the rocks at different favourable positions along the coast. Similar observations have since been repeated at various intervals, the most recent and extensive having been made in the year 1821, under the joint direction of the Swedish Cabinet and the Russian

Minister of Marine. The result, we are assured, of all these comparative admeasurements is, that, along the greater part of the Baltic, the mean level of the water is falling from three to five feet in a century, or about one foot in every twenty-five years.

“Mr. Johnson, who has made a recent inspection of the coast of the Baltic, has come to the conclusion that a change is taking place in the relative position of the land and sea, and that several small peninsulas round Stockholm were once islands; and has given proofs that at the city itself the waters are sinking, or rather the land rising.” The same author states, that “though the southern shores of the Baltic do not partake of the elevating movement, a tract extending from Stockholm to the Bothnian Gulf on the northern shores, of the length of England, is gradually rising. The discoveries of Strom and Brongniart appear to remove all doubt upon the subject. The former discovered marine deposits on the coast of Norway, at the height of four hundred feet above the level of the sea; and the latter found at the entrance of the Baltic masses of shells identical with those now inhabiting the neighbouring sea, at an elevation of two hundred feet above it.”

While these upward movements are taking place on some coasts, as exhibited by raised beaches, others manifest unquestionable indications of depression, and that within periods comparatively recent. Along the eastern and southern coast of England submarine forests are discovered, consisting of stumps of trees rooted in the soil, and standing erect, which are at many places traceable at low water and to a great extent. These submerged

forests are so extensive on the south-western coast, that Sir H. De la Beche says, that it is difficult not to find traces of them in this district at the mouths of all the great valleys which open upon the sea. As these remains of trees can be traced in many instances as far as the tide recedes, we can draw no other conclusion than that the land upon which they stand and once grew has sunken down; a conclusion from which we can no more escape, than that elevated shores with beds of shells on their summits were once and for a long time beneath the waters. The proofs are equally forcible of these opposite phenomena, which, though so opposed to our common impressions of the fixity of what our great poet calls "the sure and firm set earth," can no longer excite doubt or surprise when we consider those far greater changes of level of more ancient times, exhibited in the elevation of submarine formations above the ordinary range of the clouds, on some of the great ranges of mountains, both in the old and new continents; and on the other hand, the disappearance of very elevated land, which must have existed to furnish the materials of that on which we live, and which was manifestly formed beneath the waters by a process similar to that which is now in action.

Besides the changes effected by these elevating and depressing movements, owing to causes deeply seated beneath the strata, of which we can never arrive at any satisfactory knowledge, the surface of the earth is continually undergoing formidable changes from causes which are open to our observation. In mountainous regions of perpetual frost and snow, the rocks are shattered and dis-

located by the freezing of water in their crevices, and by the erosive power of descending glaciers; these detached fragments and finer particles are borne down by the torrents produced by rains and melting snows, and deposited in thick beds beneath, or carried on in the case of the finer matter to form alluvial land along the course of rivers, and deltas at their mouths, and in the deep sea beyond. "I have frequently observed," says Darwin, "both in Terra del Fuego and within the Andes, that when the rock was covered during the greatest part of the year with snow, it was shivered in a very extraordinary manner into small angular fragments:" and again, "as often as I have seen beds of marl, sand, and shingle accumulated to the thickness of many thousand feet, I have felt inclined to exclaim that causes such as the present rivers and the present beaches could never have ground down such masses. But, on the other hand, when listening to the rattling noise of these torrents, and calling to mind that whole races of animals have passed away from the face of the globe, during which, night and day, these stones have gone rattling onwards in their course, I have thought to myself, Can any mountains, any continent withstand such waste?"

In less elevated situations in high latitudes, the action of frost succeeded by rains or the melting of snow, and in lower latitudes the heavy periodical deluges that fall for continuous months, wash away the surface of the land, the materials of which are transported to still lower levels, or carried on to the sea to form new strata beneath its surface. The changes produced by the action of such causes are very remarkable in the north

of Italy, where the Po and the Adige bring down such quantities of detritus as to have raised their beds above the surrounding country, so as to require embankments, and the most vigilant attention in maintaining them, to prevent the waters from breaking out and inundating the country with a destructive deluge. The quantity of sedimentary matter carried down by these and other rivers, which descend from the Alps and discharge themselves into the Adriatic Gulf, has produced within the last two thousand years a tract of land along the coast of more than one hundred miles in length and twenty-two in breadth. The town of Adria, from which the sea takes its name, which was in the time of Augustus the Roman emperor a sea-port, is now twenty miles inland, and other towns have in like manner been deprived of the sea by the increase or extension of the deltas of their rivers. By such vast quantities of drifted materials, the adjoining seas are continually shoaling, and exhibit a striking exemplification of the manner in which those strata, or masses of rock, were produced, which now form the dry land, as it has been ascertained that the sedimentary matter is undergoing consolidation, and enclosing in its mass the shells of those seas.

On this subject Sir Charles Lyell observes, that the greatest depth of the Adriatic, between Dalmatia and the Po, is twenty-two fathoms; but a large part of the Gulf of Trieste and the Adriatic opposite Venice is less than twelve fathoms deep. Farther to the south, where it is less affected by the influx of great rivers, the gulf deepens considerably. Donati, after dredging the bottom, discovered the new deposits to consist

partly of mud and partly of rock; the latter formed of calcareous matter incrusting shells. He also ascertained that particular species of testacea (shell-fish) were grouped together in particular places, and were becoming slowly incorporated with the mud and calcareous precipitates.

If such is the wasting effect of the waters which form such comparatively insignificant rivers as the Po and the Adige, and the quantity of drifted matter they convey into the Adriatic, and the great changes thereby effected in the course of a few centuries, what must be the similar effect of such mighty streams as the Mississippi, the Amazons, the Orinoco and the La Plata of America; and the Ganges, the Indus, and the still greater rivers of China, with many others, each of which drains such an immense surface of country, and carries down to the sea the materials of wasted continents! The delta formed by the Ganges, one of the smallest of the above-mentioned rivers, extends 220 miles from the sea towards the interior, while its breadth along the sea coast is 200 miles; and so great is the quantity of mud brought down by this river in the time of the inundation, that the sea is rendered turbid nearly sixty miles from the mouth. From experiments made with the greatest care to ascertain the quantity of earthy matter contained in the muddy water of the Ganges in flood time, and the quantity of water discharged, it has been estimated that during the 122 days of the rainy season, no less a quantity of matter is carried down to the sea than about 400,000,000 of tons, and during the whole year more than 600,000,000 of tons, or *nearly the weight of sixty of the great Pyramids*

of Egypt. Besides the vast quantity of mud poured into the bay of Bengal, the land which forms the delta has been gained from the sea. Large portions of this delta are covered with low wood called *sunderbunds*, infested by tigers and crocodiles or *gavials*, the latter in immense numbers, whose remains, mixed with those of other animals destroyed by the inundations, must become imbedded and fossilized after the manner of those found in the older strata of the present dry land.

The stony matter brought down by the rapid waters of the Rhone forms a rocky mass at its mouth, including great quantities of shells; and a cannon was taken up from the sea near the mouth, enclosed in a calcareous rock, and is now deposited in the museum at Montpellier. The sea is found to deepen gradually from four to forty fathoms, for a distance of six or seven miles, as far as the discoloured water reaches, which may give us some idea of the extent of the deposit of stony matter from the waters of this river, which may be considered to be of the third class in point of magnitude.

The same operations are going on in inland seas and lakes. An extensive delta has been formed by the waters of the Rhone, at the upper end of the Lake of Geneva; and an ancient town called Port Vallais, formerly at the edge of the water, is now more than a mile and a half from it. From the delta, which is about five or six miles in length, the water gradually deepens; but the alluvial deposit, or mud, extends nearly two miles from the shore along the bottom. The waters which enter the lake are often exceedingly turbid, but at their exit at Geneva are remarkable for

their beautiful transparency, having deposited all the transported earthy matter. In the sediments of such lakes, land shells, and the remains of animals brought down by torrents, will be imbedded and mingled with those of fresh water shell-fish; and where rapid rivers fall into the sea, the two former will be blended with those found only in salt water: instances of this, we shall have to notice, do actually occur in some of the upper strata of the dry land. By such processes as those we have endeavoured to describe are the surfaces of our present continents undergoing continual waste and degradation, and their materials forming new strata beneath the sea; and by such means, we may fairly presume, were those strata which now form the dry land successively produced, and those vegetable and animal productions of an ancient world covered up and preserved, whose fossil forms excite our wonder and curiosity.

Before we quit the subject of the changes which have formerly taken place in the relative position of land and sea, and the wearing down of continents and formation of new strata beneath the water, the causes of which are still in operation, it may be interesting to notice that these changes did not escape the attention of the ancients. Of this we are assured by a passage in Ovid, the Roman poet, who may be considered as expressing the observations and opinions of the philosophers of his own and preceding times, which he puts into the mouth of Pythagoras, a Grecian sage who lived about 500 years before the Christian era, from whom, probably, they were principally derived. They are in substance as follows:—

1. Solid land has been converted into sea.
2. Sea has been changed into land; marine shells lie far from the distant deep, and the anchor has been found on the summit of hills.
3. Valleys have been excavated by running waters, and floods have washed down hills into the sea.
4. Marshes have become dry ground.
5. Dry lands have been changed into stagnant pools.
6. During earthquakes some springs have been closed up, and new ones have broken out; rivers have deserted their channels, and have been re-born elsewhere; as the Erasenus in Greece, and the Mysus in Asia.
7. The waters of some rivers formerly sweet have become bitter, as those of Anigrus in Greece, &c.
8. Islands have been connected with the main land by the growth of deltas and new deposits, as in the case of Antissa joined to Lesbos, Pharos to Egypt, &c.
9. Peninsulas have been divided from the main land, and have become islands, as Leucadia, and according to tradition Sicily, the sea having carried away the isthmus.
10. Lands have been submerged by earthquakes: the Grecian cities of Helice and Baris, for example, are to be seen under the sea, with their walls inclined.
11. Plains have been upheaved into hills by confined air seeking vent, as at Trœzen in the Peloponnesus.
12. The temperature of some springs varies at different periods; the waters of others are inflammable.

13. There are some springs which have a petrifying power, and convert the substances which they touch into marble.

14. Extraordinary medical and deleterious effects are produced by the waters of different lakes and springs.

15. Some rocks and islands, after having floated and having been subject to violent movements, have at length become stationary and immovable, as Delos and the Cyanian islands.

16. Volcanic vents shift their position; there was a time when Etna was not a burning mountain, and the time will come when it will cease to burn. Whether it be that some caverns become closed up by the movements of the earth, and others opened, or whether the fuel is finally exhausted, &c.

Aristotle, a Greek philosopher of a later age, appears to have entertained similar notions; and he remarks that "the changes of the earth are so slow in comparison with the duration of our lives, that they are overlooked; and the migration of people after great catastrophes, and their removal to other regions, cause the events to be forgotten."

Strabo, a philosopher who lived in the reigns of the Roman emperors Augustus and Tiberius, speaking of the mutations of land and seas, says, "It is not because the lands covered by the sea were originally at different altitudes that the waters have risen or subsided, or receded from some parts and inundated others; but the reason is, that the land is sometimes raised up, and sometimes depressed, and the sea also is sometimes raised and depressed, so that it either overflows or returns into its own place again. We must, *therefore*, ascribe the cause to the ground which

is under the sea, or to that which becomes flooded by it; rather, however, to the former, for that is more movable, and, on account of its humidity, can be altered with greater celerity. It is proper," he observes in continuation, "to derive our explanations from things which are obvious, and in some measure of daily occurrence, such as deluges, earthquakes, volcanic eruptions, and sudden swellings of the land beneath the sea; for the last raise up the sea also, and when the same lands subside again, they cause the sea to be let down. And it is not merely the small islands but the large islands also, and not merely the islands but the continents, which can be lifted up together with the sea, and both large and small tracts may subside; for habitations and cities, like Bare and Bizona, and many others, have been engulfed by earthquakes."

At a much later period the Arabian philosophers were also aware of the successive changes of land and sea. Mohammed Kazwini, who lived about the end of the thirteenth century, in allusion to these phenomena gives the following beautiful fable of the travels of an ideal personage, illustrative of such changes:—"I passed one day by a very ancient and wonderfully populous city, and asked one of the inhabitants how long it had been founded. 'It is indeed a mighty city,' replied he, 'we know not how long it has been founded, and our ancestors on this subject were as ignorant as ourselves.' Five centuries afterwards, as I passed by the same place, I could not perceive the slightest vestige of the city. I demanded of a peasant who was gathering herbs on its former site, how long it had been destroyed.

‘In sooth, a strange question,’ replied he; ‘the ground here has never been different from what you now behold it.’ ‘Was there not of old a splendid city here?’ ‘Never,’ answered he, ‘so far as we have seen; and never did our fathers speak to us of any such.’ On my return, 500 years afterwards, I found the sea on the same place, and on its shores were a party of fishermen, of whom I inquired how long the land had been covered by the waters? ‘Is this a question,’ said they, ‘for a man like you? The spot has always been what it is now.’ I again returned 500 years afterwards, and the sea had disappeared. I inquired of a man who stood alone upon the spot, how long ago the change had taken place, and he gave me the same answer I had received before. Lastly, on coming back again, after an equal lapse of time, I found there a flourishing city, more populous and more rich in beautiful buildings than the city I had seen at the first time; and when I would fain have informed myself concerning its origin, the inhabitants said, ‘It is lost in remote antiquity; we are ignorant how long it has existed, and our fathers are as ignorant on the subject as ourselves.’”*

* Lyell, *Principles of Geology*, p. 21.

CHAPTER III.

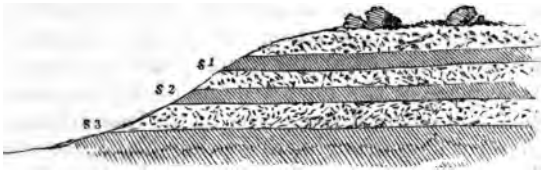
Origin of Springs and Rivers, and the enormous quantity of Water discharged by the latter—Causes which influence the discharge of Springs—Intermitting Springs—Artesian Wells: the principle of them explained; several of them noticed: that of Grenelle.—Hot Springs: the cause of them explained—Causes of the failure of some attempts to obtain Water by the Artesian method.—Mineral Veins: Rocks containing them; those of Sweden and Cornwall; contents of the Veins; depth to which some of them are worked—The powerful Pumps used in mining operations in Cornwall; immense quantity of Water discharged by them—Direction of Metallic Veins—Displacement of Veins by Dykes, or Veins of Porphyry—Situations in which the richest Metallic Veins are found in Cornwall, Derbyshire, and Cumberland; those of foreign countries—Rocks in which Metallic Veins are most abundant in all countries—Cause assigned of the deposition of Metallic Ores in Veins.

ALL springs are derived from water which rises by evaporation from the surface of the sea and land, and is again condensed in rain and snow, and sinks into the earth. It has been estimated that about two-thirds of the water which falls upon the land are again exhaled from the surface, and therefore it is the remaining third which supplies the surface and the springs, and is conveyed again to the sea by the natural drainage of the land, the channels of rills, rivulets, and rivers. The effect of the silent but universal process of evaporation becomes very striking, when we consider the immense quantity of water discharged by a single river which drains an extensive surface of country; and this is nowhere so astonishingly exhibited as at the falls of Niagara, where the collected waters of a large portion of the continent of North America, after forming in

their progress extensive lakes or inland seas of fresh water, descend perpendicularly in one immense body, 25 feet deep, and about 800 yards of total width, with a fall of 160 feet to the lower level, exhibiting a spectacle of terrific grandeur, more awful than imagination can conceive or words describe. Yet even this vast collection of waters, which forms the river St. Lawrence, is very inferior to that which is discharged by the Mississippi, or either of the two greatest rivers of the southern continent, the Amazons and the La Plata, and one or two others which drain the eastern part of Asia. The Ganges, though far inferior in the length of its course and the space which it drains to either of the rivers above-named, is estimated by Mr. Everest to discharge during the period of flood 500,000 cubic feet of water per second.

That portion of the water which is not discharged at once from the surface, or again evaporated, sinks into the earth till it meets with an impervious stratum either of clay or rock, and is ultimately conveyed out at some lower level, producing springs where the impervious stratum terminates upon the surface. Many springs are known to issue below the level of the sea, and discharge their waters into it at various depths; and some of them are so copious, that over the part where they discharge, ships obtain a supply of fresh water. Those springs which issue at the lowest levels on the land, are always the most constant, and generally the most abundant; while those which appear near the surface are not only less constant, but sometimes cease to discharge *after long droughts*. The cause of this dif-

ference it is not difficult to understand. The mass of earth through which the water percolates is the true reservoir, and if the impervious bed which arrests its progress be near the surface, the quantity of water discharged by the spring will be more or less irregular according to the seasons; that is, it will be greatest soon after plentiful rains, and least after considerable periods of drought, owing to the limited depth of the pervious stratum or reservoir above. When, on the other hand, the pervious stratum is of considerable depth, the reservoir is enlarged, and the irregularity of supplies from the surface is less and less felt in proportion to the increased depth through which the water has to descend; so that the deepest or rather the lowest springs appear to undergo no perceptible diminution. This variation in the constancy of springs is often manifested in deep valleys, which cut through several strata of no considerable thickness, which are alternately porous and retentive. The following section will assist in giving a clearer idea of the nature of such springs:—

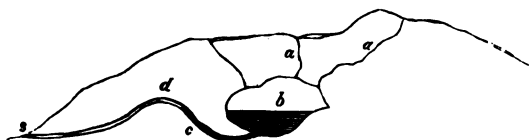


In the above section, the dotted spaces represent porous beds or strata, either of sand or rock, with numerous fissures or cracks, and the other spaces, beds of intervening clay or marl. The latter, except when they are of immense thickness, are

seldom so continuous and perfect, but that they admit of a considerable quantity of water passing through them into the porous mass beneath, so as to keep the lowest of them constantly supplied from above. The whole, therefore, taken together, may be considered as one great reservoir, but discharging springs of greater or less constancy according to their relative position at the points *s s s*, along the sloping face of the hill,—but generally the most copious, and always the most constant, at the lowest point. When rocks are of great thickness and have extensive fractures, the water is sometimes collected in a great body, and poured forth in such a copious volume, as to form a powerful mill-stream at the source, of which there are remarkable instances at Holywell in Flintshire and Cheddar in Somerset. These springs issue from the mountain limestone, which generally affords the most copious and constant supplies, and both of them turn several mills within a very short distance of the spot from whence they issue.

Referring again to our section, it must be evident that, in ordinary cases, the quantity of water thrown out by a spring must depend upon the greater or less extent of the bed of clay that obstructs its downward course; and its issue will take place at the lowest point of the impervious bed, and where it is opposed by the least resistance. After a long drought, the spring No. 1, from having the least depth of porous earth above it, will be the first affected and the most irregular in its supply of water; No. 2 will be less variable; and No. 3 the most constant, from being supplied from a larger and deeper mass of pervious earth. *In many instances, where the upper porous stra-*

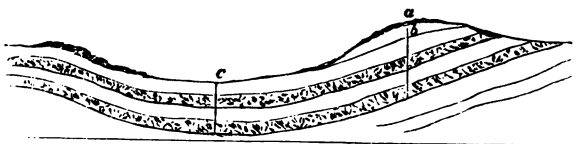
tum is very shallow, the upper springs cease after a long continuance of dry weather, and again pour out abundantly after heavy rains. Such springs may be properly called intermitting. But there are some springs which are always intermitting at short intervals throughout the year, owing to a peculiar accidental form of the fissures and cavities from which they are supplied, which the subjoined cut will explain:—



The above may be supposed to represent a mass of rock, with a cavity or natural reservoir, with fissures for the ingress and egress of the water. The surface water descending through the fissures *a a a*, accumulates in the cavity or reservoir *b*, but as the only outlet is by the fissure or natural pipe *c*, no water will be discharged until it rises in the reservoir above the level line of *d*; when, however, that has taken place, the pipe *c* acts as a syphon, and discharges the whole of the water in the cavity at the point *s*; after which, the spring ceases until the water has again risen to the required level. As here represented, that water has not arrived at that level.

When a well is sunk in a porous stratum, into one that is retentive, the water rises in the well to a height depending upon the depth of the porous bed, which, indeed, should be considered the true reservoir which constantly replenishes the cavity of the well.

Water is often brought to the surface by sinking what are called Artesian wells, a name derived from Artois in France, where this ingenious method was first adopted. This mode of obtaining water depends upon certain conditions of stratification, or form of the porous and retentive strata, which not unfrequently occur. The conditions of success, and the cause of the ascent of the water in these wells, will be sufficiently explained by the following representation; in which it will be seen, that the beds or strata have been deposited in a basin-shaped cavity or depression, or have subsequently had their position so altered as to take that form, either by the sinking down of the central part or the elevation of the extremities.



The blank spaces are intended to represent impervious beds of clay, and the dotted spaces porous materials for containing water. The water enters the porous beds at the outcrop at either extremity, but is prevented from issuing at the surface by the beds of clay which overlie them; though, if it had free egress, it is obvious that it would rise to the same level, or nearly so, as the outcrop of the porous beds containing it. If, under such circumstances, a well be sunk at *a* into the porous bed, the water will rise no higher than the *b*, that being the level of the outcrop or

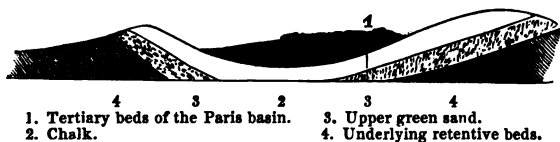
surface of the porous beds which supply it, and a pump will be required to bring it to the surface. But if a hole be bored at the depressed part at *c* into the same porous strata, a point of the surface which is much lower than the outcrop of these beds, the water will overflow with a force proportioned to the difference of level. In cases where, as in the instance here figured, two or three successive beds of sand and clay occur, it must be obvious that by sinking deeper, a larger supply of water would be obtained than if the well or bore had penetrated only to the first porous bed.

The water which supplies the fountains at Charing Cross was obtained, first, by sinking deep wells, and then boring down to a greater depth; into this bore was inserted a jointed cast-iron tube, through which the water ascended in great abundance into the well, but did not rise to the surface; and thus the aid of a pump was required to lift it into a reservoir for the supply of the fountains. The same method has been resorted to by the great brewers of London, who obtain by this means a copious supply of the purest water. At Sheerness, a well was sunk and bored 382 feet below the clay, in which, in the course of a few hours, the water rose above the surface. Another Artesian well was sunk at Fulham to the depth of 317 feet, in which the water immediately rose to the surface, and discharged 50 gallons per minute. At the Duke of Northumberland's, above Chiswick, a boring was made to the depth of 620 feet, when a considerable supply of water was obtained, which rose 4 feet above the surface. At Tooting, a sufficient supply of water was obtained to turn a wheel which raised

water to supply the upper part of the house; and at Tours, in France, after boring several hundred feet, the water rose 32 feet above the surface, and amounted to 300 cubic yards in twenty-four hours. But the most extraordinary achievement of this kind, was that at Grenelle, one of the suburbs of Paris, both as regards the width and depth of the boring and the supply of water obtained. The work was commenced with an auger of a foot in diameter, and continued through all the tertiary strata into the chalk, and through that stratum to the depth of 1,800 feet. At the depth of 500 feet, a nine-inch auger was used; and at 1,300 feet, one of six inches. When the great body of the water was reached, at the above enormous depth, it rushed up with great violence, and at a temperature of 82° Fahr., many feet above the surface; and has continued to afford a constant supply ever since, of about half a million gallons in twenty-four hours.

This great work, so successfully accomplished, was conducted by the light afforded by geological science. Paris is situated, like London, on the tertiary or newest strata, resting upon a basin of chalk with green sand beneath; and the form and nature of these strata afforded to scientific men the strongest assurance that by perseverance, with a large bore, a great body of water would ultimately be obtained. Great discouragement was, however, felt, when at the depth of 1,500 feet no adequate quantity appeared; and nothing but the strong conviction afforded by geological knowledge would have justified a continuance of the work, which was ultimately crowned with *such* admirable success. The reason for such

perseverance will appear in the annexed section of the strata beneath Paris:—



The high temperature, 82° Fahr., at which this water rose and which it continues to maintain, corresponds nearly with what is found in mines of an equal depth. In every country where the earth has been penetrated, it has been found that, after a point has been reached where the temperature corresponds with the mean heat of the climate, which in our latitude is about 50° Fahr., the thermometer rises at the rate of one degree for about every sixty feet of descent; and though the rate of increase varies in different localities, the universal prevalence of increased temperature has led to the opinion, that this must be owing to a general high temperature at great depths in the earth, and that thermal springs derive their heat from the same source. The phenomena of hot springs, though they frequently occur in the neighbourhood of volcanoes, appear to be independent of them, as they are found in countries where no volcanoes exist; nor do they seem to be the effect of chemical action, as the waters of the hottest springs are remarkable for their purity, or the small quantity of mineral matter they hold in solution. Humboldt observes, that the hottest spring he found in South America rose through granite, and was very remote from any volcanic vent.

Admitting the general prevalence of heat at great depths in the earth, it is not difficult to account for hot springs, which are found in almost every part of the world. The dislocation which the strata have everywhere more or less undergone, must in numerous instances have produced fissures to an immense depth; into such fissures the water finds easy access, and to a depth where the rocks are constantly at a very high temperature, and impart their heat to the waters, which being by this means rendered lighter, constantly rise to the surface with a heat corresponding with the depth to which they have penetrated. If hot springs abound more in volcanic regions than elsewhere, it is probably owing to more frequent fractures of the strata: and perhaps the origin of the volcano itself and its occasional activity may be owing to the water descending to depths where the heat is sufficiently great to produce by its presence intense chemical action and explosive effects. This cause of volcanic action is the more probable from the circumstance, that all the great volcanoes are either on islands or on those parts of the continents which border upon the sea, or if in the interior, near salt lakes; and also from the fact, that they emit immense quantities of watery vapour and muriatic acid, one of the components of sea-salt.

Reverting to the subject of Artesian wells, the probability of obtaining water by their means depends upon the geological structure of the country. The most favourable situations are those where alternate porous and retentive strata crop out at no great distance, and rise to a considerable *elevation*; under such circumstances, the finding

of water which would rise above the surface would almost amount to a certainty, though there are sometimes hidden causes, which defeat the most rational and well-founded expectations—such as dislocations and curves in the strata. To guard against such causes of failure, cast-iron pipes should be inserted in the bore. By means of Artesian wells a plentiful supply of water may often be obtained to flow over the surface, which, otherwise, would find its way through the porous strata to some remote point, where it would be unavailable.

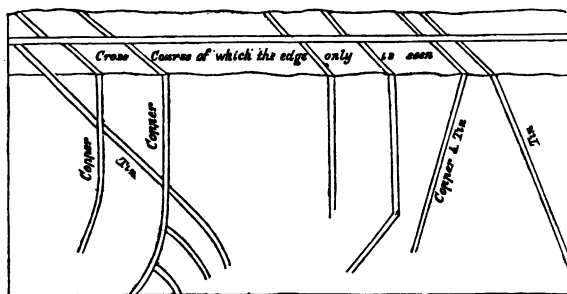
MINERAL VEINS.

The ores of metals are found in beds and veins, in both primary and secondary strata, and also in unstratified rocks. The metalliferous ores in Sweden occur in beds in primary mountains; and beds of lead, zinc, and iron are found abundantly in secondary rocks. In England, also, some ores are found in beds, and always those of iron; but those of the other metals exist in veins. Veins or lodes, as they are called in Cornwall, are fissures or rents in rocks, of greater or less breadth, varying from a few inches to several feet, of various degrees of inclination, and sometimes nearly perpendicular. The veins containing tin and copper generally run nearly east and west, though with considerable variation; while those which are charged with lead, silver, and cobalt, have a northern direction; and when they cross, or intersect, as frequently happens, those containing tin and copper are invariably cut through and displaced, evidently showing the priority of formation of the latter. The substances generally filling the

veins in which the ores are confusedly blended, differ from the materials of the inclosing rock. Veins run for several miles in length without any decided termination, and are of unknown depth. Some of these have been worked to the depth of more than 1,500 feet. In general these metalliferous veins are from one to three feet in breadth, and these are preferred by the miner, because the ores they contain are not so much mixed with other mineral substances as those of wider veins. Some parts of veins contain no ores, and are therefore called *deads* by the miners; others are entirely empty, but these are of rare occurrence. Water prevails in all metalliferous veins, and is one of the most serious impediments to the operations of the miner; so that before the invention of the steam-engine the mines could not be wrought to any considerable depth. Pumps are now employed of immense power and matchless perfection, by which, throughout the mining districts of Cornwall, enormous quantities of water are raised day and night from the greatest depths.

The situations of veins are often indicated at the surface by an ochrous substance called *Gossen* by the Cornish miners, and the ores are generally found at about 80 or 100 feet from the surface. Both copper and tin ores are frequently found in the same vein, and sometimes accompany each other to the greatest depths. Dykes or veins of porphyry, called *Elvan* by the miners, often cut through the metalliferous veins and heave them out of their course, to the great hinderance and perplexity of the miner. Veins of copper ore also displace those of tin. These displacements sometimes amount to hundreds of feet, and are the

cause of great delay, and often of enormous expense, before the intersected vein can be again discovered. The walls or sides of the veins are called by the miner the *country*, and the immediate surface of the rock differs from the general mass, being sometimes harder and at others softer. The intersecting veins, which contain no metals, are called *cross courses*, and the direction of the vein at the surface is called the *strike* and *direction*. When the underlie or slope is considerable, the upper side of the confining rock is called the *roof*, and the under side the *floor*; but when the sides are nearly perpendicular, they are called the *walls*. Metallic veins often divide, and form what are called *strings* or *pipes*, and, when very small, *threads*. The section beneath of a mine affording tin and copper ore, with a cross course, will enable



North and south section of a Tin and Copper Mine.

the reader to form some idea of the ordinary direction of such metallic veins, and of the manner in which they intersect each other, and are displaced by the cross courses.

In the above section it will be seen that the cross course has intersected and displaced all the lodes, and that the two lodes of copper cut through one of tin without displacing it.

The mineral substances which fill up the lodes have little or no resemblance to the confining rocks; they consist chiefly of silex, with fluor spar and carbonate of lime in a crystalline state, and with these the proper ores are variously commingled and united, in very variable quantities, as a vein in one place rich becomes often in another very poor. In Cornwall the copper lodes are observed to be the richest at the junction of the granite and schist, or slate, and that the best tin mines are in the former rock. In Derbyshire the veins of lead traverse both the carboniferous limestone and the sandstone, and though rich in the limestone, become poor, and of no value, in passing through the other. In the county of Cumberland veins of lead ore pervade the limestone shales and sandstone, but are invariably the richest in the limestone. At Alston Moor the whole of the lead is obtained from this rock. In the lead districts of England, the veins which are productive run east and west, and are traversed by cross courses at right angles to them.

There is every reason to believe that the mineral veins were not formed at the time of the consolidation of the containing rocks, but that the rents or fissures have been subsequently produced and filled with those mineral substances which they contain, and which differ so much from the rocks themselves. It is evident that many of them must have been formed after others had been filled up, from the copper lodes cutting through those of

tin, while the cross courses and newer metalliferous veins displace both, and produce those numerous faults which often obstruct and baffle the miner.

Mineral veins appear to be very partially distributed, as in many large portions of the surface of the earth none have been discovered. They are generally found in hilly, mountainous, and sterile districts, the least inviting as places of habitation, from their great elevation and consequent general destitution of wood. The best mining district of Cornwall, which affords all the tin and nearly the whole of the copper raised in England, though of no great elevation, presents a sterile aspect.

The lead mines of Derbyshire and of the north of England are situated in elevated and wild districts; but the deep sunk valleys which descend from these regions often exhibit the most picturesque and romantic beauty, particularly those watered by the Tyne, the Wear, and the Tees. The mountain districts of Scotland and North Wales, and the elevated tracts of Wicklow and Wexford, in Ireland, are also rich in mineral productions; and it is the good fortune of the British Islands to excel all Europe in mineral wealth, of which the principal are coal and iron.

Of foreign countries we may observe, that central France, and the Vosges mountains on its eastern frontier, afford rich veins of galena (sulphuret of lead) containing much silver, with copper, manganese, and other metals; and ores of both iron and gold are found in the south. Spain possesses valuable mines of quicksilver, in the province of La Mancha, generally found in the state of cinnabar, or sulphuret of mercury; lead

ore is also abundant, and the mines of both are of great antiquity. Italy affords valuable metals, and the island of Elba contains an immense quantity of fine iron ore, which has furnished that metal from the earliest recorded times. In Germany, the Hartz mountains of the north, and those which divide Bohemia and Saxony, and Austria in the south, produce silver, copper, lead, and iron, with some tin and gold; while Hungary affords veins of native silver, and ores of lead, zinc, and iron. Sweden and Norway are both very rich in copper and iron. In Russia, the Ural Mountains, which divide Europe and Asia, are prolific in minerals, particularly in gold, which is found in sands mingled with iron pyrites, and also yield the rare and valuable metal, platinum, with copper and iron.

South America, including Mexico, is proverbial for its great mineral treasures of gold, silver, and copper. Gold abounds in Brazil, and the mines of the north of Chili yield immense quantities of silver. The mines of Pasco alone yielded, it is said, about 180,000 lbs. of silver annually, (some of these mines are many thousand feet above the level of the sea;) while the silver mines of Potosi, in Peru, are scarcely less productive. Iron is also abundant in most of these districts. The mountainous regions of North America, particularly the Rocky Mountains in the west, are said to be rich in metallic veins, hitherto but little explored, though the extraordinary abundance of gold recently discovered in California affords a promise of greater mineral wealth than even the long celebrated regions of the south.

It is a remarkable geological fact that all the

districts mentioned above, both in Europe and America, as affording metalliferous veins, exist in the older sedimentary and metamorphic rocks, such as clay slate, quartz rock, mica schist, and gneiss, which have undergone great disturbance, and that the metals abound most where the igneous or unstratified rocks come in contact with the sedimentary.

With regard to the manner in which the fissures of rocks have been filled up with metallic ores and other substances differing from the rocks themselves, nothing has yet been satisfactorily determined, nor perhaps ever will be, though the subject has much engaged the attention of some of the most profound geologists; but Mr. Fox, of Falmouth, has shown, by some very remarkable and ingenious experiments, which his previous observations upon mineral veins led him to make, that there is a high probability that the deposition of the substances has been principally, if not entirely, effected by electric or galvanic currents passing through the water contained in their fissures, and thus causing the deposition of the mineral matters which they held in solution, by a similar action to that of the modern invention of electrotype plating, by which metals are precipitated from their solution in acids. If this opinion should be confirmed by future investigation, it will afford another instance of the wonderful phenomena of nature which the science of chemistry has unveiled to mankind, and an additional proof of the constancy of those laws originally impressed upon matter by Divine wisdom and power, which have operated through such immense periods of time as to produce the effect

in question. Half a century ago, no day-dream of a disordered imagination would have been thought more wild than such a supposition as that above-mentioned; yet inductive reasoning upon the known laws of electro-chemical action, and experiments founded thereon, bid fair to explain one cause at least of the obscure geological phenomena exhibited by mineral veins.

CHAPTER IV.

The British Strata—Geological Map by Professor Phillips—Tabular arrangement of British Geology, exhibiting the order, character, and some of the localities of the different Strata and Rocks—Recent and superficial Formations—Alluvial Deposits of Rivers and their Estuaries—The Fens of Lincolnshire and Marshes of Somerset—Marine Alluvium—Banks of Pebbles on the South Coast, and the Calcareous Sands of Devon and Cornwall—Encroachments of these Sands at Hayle, Perranzabulo, and Padstow—Loo Harbour—Encroachment of Sand-hills on the coast of the Bay of Biscay, and their destructive effects.

FROM the foregoing general observations on geological phenomena, or the structure of the visible features of the crust of the earth, with which we have thought it needful to premise this work, we shall now proceed to give a description of the British strata, commencing with a tabular arrangement, for the purpose of exhibiting at one view the whole of the series, from the most recent deposits to the metamorphic and primary rocks, under the divisions and subdivisions most generally adopted by British geologists. This together with the geological sections at the end of the work will enable the reader, with very little application, to fix in his mind a correct idea of the order of superposition of the several strata, and readily to assign to each, when separately considered, its proper place in the general series. In describing the strata reference will be occasionally made to a geological map of the United Kingdom by Professor Phillips, recently published at a very moderate price. It is scarcely needful to observe that the inspection of such a map is almost indispensable to a correct and clear understanding of the subject, and will very much facilitate the progress of the

inquirer. The table will contain all the rocks found in any part of the British Islands. We must, however, remark, that though the order of superposition is constant, as indicated by the fossil remains and mineral characters, the sequence is sometimes broken; that is, rocks which appear in one direction, either do not exist, or are overlaid and obscured in others.

A Table of the British Strata,

ARRANGED IN THE ORDER IN WHICH THEY OCCUR,

COMMENCING WITH THE UPPERMOST OR MORE RECENT.

ALLUVIUM, OR ALLUVIAL BEDS.

	<i>Character.</i>	<i>Some of the Localities.</i>
<i>Deposits of Rivers.</i>	Sand, mud, or silt.	Banks and bottoms of rivers, deltas at the mouths of rivers, bottoms of lakes.

TERTIARY STRATA ABOVE THE CHALK.

<i>Ancient Superficial Deposits</i>	{ Sand, clay, and gravel, composed of drifted fragments of strata, both near and distant, containing the bones of elephants and other large animals.	Everywhere in valleys and the plains beyond. Often on the sides and summits of hills and high inland levels. London, Oxford, Gloucester, Harwich, Valley of the Avon, Bath, &c.
<i>Crag, Norwich, Red, and Coralline ...</i>	{ Sands, clays, and marls, with imbedded shells and corals, and the remains of land animals in the upper bed.	Coasts of Norfolk, Suffolk, and Essex, resting upon the London Clay, and in some places upon the Chalk.
<i>Freshwater and Marine Beds : of the Isle of Wight</i>	{ Limestone, with clay and sand; and beds of marl containing freshwater and marine shells.	Headon Hill, Binsted, Shalcombe, Whitecliff Bay, Isle of Wight.
<i>Bagshot Sand</i>	{ Sands, sandstones, and flint pebbles, with argillaceous beds.	Bagshot Heath, Hampstead and Highgate Hills, Brackleshambay.
<i>London Clay</i>	{ Lead-colour or blue clay, containing nodules of cement-stone, with fossil shells and seeds.	London, Isle of Sheppy, Highgate Hill, Richmond, Coast of Hampshire.

TERTIARY STRATA ABOVE THE CHALK—*continued.*

	<i>Character.</i>	<i>Some of the Localities.</i>
<i>Plastic Clay</i>	{ Blue, yellow, and white clay; sands; and flint pebbles, much water-worn and rounded.	Woolwich, Blackheath, Reading, Poole, Alum Bay, Isle of Wight.

NEWER SECONDARY STRATA.

CRETACEOUS SYSTEM.	<i>Upper Chalk</i>	{ Soft marking chalk, with beds and nodules of flint.	Marlborough Downs, Salisbury Plain, South Downs, Dover Cliffs, Brighton, &c. &c.
	<i>Lower Chalk</i>	{ Harder than the above, with but few flints.	Flamborough Head, Warminster, Shakspeare's Cliff, near Maidstone.
	<i>Chalk Marl or Malm</i>	{ Clayey grey chalk, without flints, passing into grey sand and marl. Firestone.	Benson, Oxfordshire; Vale of Pewsey, Wilts; Guildford, &c.; Folkstone, Merstham.
	<i>Upper Green Sand.</i>	{ Sand and sandstone, with particles of silicate of iron.	Devizes, Warminster, Wantage, Vale of Pewsey, Shaftsbury.
	<i>Gault</i>	{ Dark blue clay, with small concretions and numerous fossils.	Folkstone; Maidstone; Isle of Wight; Devizes, Wilts.
	<i>Lower Green Sand.</i>	{ Sands and sandstone, with beds of chert and limestone (Kentish Rag).	Black Down, Somerset, and Devon; Maidstone, Kent; Isle of Wight.

MIDDLE SECONDARY.

WEALDEN SYSTEM.	<i>Wealden Clay and Iron, or Hastings Sand</i>	{ Weald clays, with Petworth marble, Purbeck beds of limestone; Tilgate grit, or Hastings sands.	Wealds of Kent and Sussex; Isle of Purbeck; Lulworth; Vale of Wardour; Isle of Wight.
	<i>Portland Stone</i>	{ Imperfect gritty limestone, containing beds and nodules of chert. Building-stone of London.	Isle of Portland; Swindon; Aylesbury; Tisbury, Wilts.
OOLITE SYSTEM.	<i>Kimmeridge Clay</i> ..	{ Blue shaly clay, with nodules of septaria.	Shotover Hill, Oxford; Isles of Purbeck and Portland; North Wilts.
	<i>Coral Rag</i>	{ Imperfect limestone, with shells and fossil corals.	Calne, Wilts; and Kirby Moor, Yorkshire.
	<i>Calcareous Grit</i>	{ Siliceous and shelly sandstone.	Abingdon; Weymouth; Filey, near Scarborough.
	<i>Oxford Clay</i>	{ Blue and yellow clay, with Melbury marble turtle stone, or septaria.	Oxford; Christian Malford; Bedford; Vale of Blackmoor, Dorset.
	<i>Kelloway Rock</i>	{ Coarse sandy limestone, with ammonites and other shells.	Scarborough; Kelloway Bridge, near Chippenham, Wilts.

MIDDLE SECONDARY—continued.

	Character.	Some of the Localities.
OOLITE SYSTEM—continued.	<i>Cornbrash</i>	{ Imperfect limestone, often blue and sandy. Malmesbury and Trowbridge, Wilts; Atford, Wrexhall, Chippenham, Wilts.
	<i>Forest Marble</i>	{ Coarse slaty limestone, abounding in shells. Hinton, nr. Bath; Melbury, Dorset; Frome.
	<i>Bradford Clay</i>	{ A tenacious brown clay, sometimes shaly, abounding with fossil shells and corals. Bradford, Wilts; Cirencester.
	<i>Great Oolite</i>	{ Yellow freestone, with fragments of shells (Bath stone). Farley and Combe Downs; and Bathford Hill, near Bath.
	<i>Stonesfield Slate</i> ...	{ Calcareo-siliceous slate, sometimes passing into sand with shale. Stamford; Stonesfield, Oxon; Sevenhampton, nr. Cheltenham; Cleaveland Hills, Yorkshire.
	<i>Fullers' Earth</i>	{ A brown clay, containing fullers' earth. Sides of the hills round Bath; Olddown and Fortnight, near Bath.
	<i>Inferior Oolite</i>	{ Coarse freestone, abounding in shells, reposing upon deep beds of calcareous sand, with beds of marl. Bath, Doulting, Mendip Hills, and Ham Hill, Somerset; Dundry Hill; Cotswold Hills, Gloucestershire; Beechen Cliff, and Beacon Hill, Bath; Yeovil and Ilminster, Somerset.
RED SANDSTONE SYSTEM.	<i>Lias</i>	{ Blue slaty marl or clay, with beds of blue and white Lias limestone, containing large ammonites and fossil bones of reptiles. Whitby, Yorkshire; Vale of Bath; Lyme Regis, Dorset; Churton and Street, Somerset, &c. &c.
	<i>New Red Sandstone, or Red Marl</i>	{ Red clay or marl. Cliffs at Sidmouth; Plains of Worcester and Cheshire; Warwickshire, Nottinghamshire, &c. Sands and sandstones, with interspersed and accumulated beds of pebbles of older rocks. Dawlish; Exeter; Western Valleys of Somerset; Shropshire, and many Midland Counties; Gypsum, rock-salt, and brine springs. Nampwich; Droitwich.

OLDER SECONDARY STRATA.

CARBONIFEROUS PERMIAN SYSTEM.	<i>Magnesian Limestone</i>	{ Yellowish sub-crystalline limestone. Building stone of York Minster and the Houses of Parliament. Nottingham, Mansfield, Notts; Knaresborough, Yorkshire; Sunderland; Wokey Hole, Somerset; Exeter.
	<i>Coal Measures</i>	{ Beds of coal and culm, alternating with layers of shale, sand, and hard gritstone, and sometimes limestone. Northumberland, Scotland, Derbyshire, Lancashire, Shropshire, Staffordshire, North and South Wales, Gloucestershire, Somerset.

OLDER SECONDARY STRATA—*continued.*

	<i>Character.</i>	<i>Some of the Localities.</i>
CARBONIFEROUS SYSTEM— <i>continued.</i>	<i>Millstone Grit</i>	Coarse siliceous sandstone, containing mica and pebbles. Flagstones of London, and grindstone beds.
	<i>Mountain or Carboniferous Limestone</i>	Blue or reddish compact limestone; secondary marble of Derbyshire, abounding in caverns and deep fissures, and containing ores of lead and calamine. Sometimes alternating with beds of shale, chert, and gritstone, and penetrated with trap-rocks; often full of shells and corals.
		Accompanying the coal measures from Derbyshire to Northumberland.
DEVONIAN, OR OLD RED SANDSTONE SYSTEM.		Mendip, Somerset; Hot Wells, Bristol; South Wales. Banks of the Wye, Monmouthshire; Matlock, &c., Derbyshire, Lancashire, Westmoreland, Cumberland, and Northumberland.
	<i>Old Red Sandstone.</i>	Derbyshire.
		Sandstones and conglomerates of pebbles; limestones called cornstones, and marls alternating with slaty beds of sandstone.
SILURIAN SYSTEM.	<i>Devonian Rocks</i>	Cumberland; Hereford; Shropshire; Monmouth; Brecon. Mitchel Dean, Gloucestershire, and Portishead Point, near Bristol. Several parts of Scotland.
		The so-called Greywacke rocks and slates of Somerset, North and South Devon, and Cornwall, with slaty limestones and secondary marbles.
		Quantock, Somerset; Exmoor; Ilfracombe, Coomb-Martin, and Kingsbridge, Devon; St. Colomb, Portreath, and Truro, Cornwall; Plymouth and Babbicomb, Devon.
	<i>Upper Silurian</i>	Blue and grey clayey limestones; dark shales and flagstones, containing marine shells and fishes.
		Ludlow Castle, Shropshire; Aynestry and Woolthorpe, Herefordshire.
		Crystalline blue and grey limestones, with various fossils.
		Dudley Castle. Worcestershire; Wenlock Edge, Iron Bridge, Shropshire.
		Dark grey shale, with nodules of sandstone.
		Wenlock, Shropshire.
	<i>Lower Silurian</i>	Caradoc shelly limestone, and greenish sandstones, with corals and shells.
		North and South Wales; Horderly, Shropshire; May Hill, Gloucestershire.
		Llandello flags and limestone; freestone grits and limestone; dark-coloured flags; beds of schist, with shells and trilobites (a fossil crustaceous fish).
		Llandridod, nr. Builth; Radnorshire.

OLDER SECONDARY STRATA—*continued.*

	<i>Character.</i>	<i>Some of the Localities.</i>
CAMBRIAN SYSTEM.	<i>Plynlimmon Rocks.</i> { Slates with beds of conglomerate.	Plynlimmon, Cardigan.
	<i>Bala Limestone</i> { Dark limestone, with slates; a few fossils.	Bala, Merionethshire.
	<i>Snowdon Rocks</i> { Fine-grained blue roofing slates, with few fossils.	Snowdon, Caernarvonshire.
	[The above are now generally referred to the Silurian System.]	
	<i>Cambrian and Cambrian Slates</i> {	{ Longmynd Hills, Shropshire; Barmouth; Cardiganshire; Keswick and Grassmere, Westmoreland; Mull of Galloway; and Lammermuir Hills, Scotland.

PRIMARY STRATIFIED CRYSTALLINE ROCKS.

<i>Chlorite Schist</i>	{ Composed of quartz and chlorite, laminated.	{ Ben Lawers, Ben Lomond, Loch Awe, Mull of Cantyre, Scotland.
<i>Mica Schist</i>	{ Laminated and granular, and composed principally of quartz and mica.	
<i>Gneiss</i>	{ Laminated and granular, and composed of quartz, felspar, and mica. The strata of this and the above rocks are very much contorted or twisted, and they are sometimes more or less associated with crystallized limestone, or marble, hornblende slate, granular and compact quartz rock, &c.	{ Grampian Hills, Benmore Hills, Loch Rannoch, Loch Gil, Isles of Tiree and Coll, and Western Isles, Scotland.

UNSTRATIFIED ROCKS.

<i>Granite</i>	{ Grey, red, and white, and composed of crystalline grains of quartz, felspar, and either mica or hornblende.	{ Aberdeen, Peterhead, Cairn Gorm, Scotland; Mount Sorrel, Leicestershire; Malvern Hills, Worcestershire; Dartmoor, Devon; Banks of the Tamar, and Land's End, Cornwall.
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TRAP ROCKS.

	<i>Character.</i>	<i>Some of the Localities.</i>
<i>Porphyry</i>	(These are unstratified and crystalline rocks, which, in a molten state, have penetrated, fractured, and upraised many of the stratified rocks, and produced dikes and faults.	Mines and mining districts of Cornwall; Salisbury Craigs; Edinburgh; Isle of Staffa; Cleve Hills, Shropshire. Mountain limestone, Derbyshire; Wrekin Hill, Shropshire; Malvern Hills, Worcestershire; Lizard, Cornwall.
<i>Green Stone</i>		
<i>Basalt</i>		
<i>Toadstone</i>		
<i>Compact Pelspar</i> ...		
<i>Syenite</i>		
<i>Serpentine</i>		

RECENT AND SUPERFICIAL FORMATIONS.

In giving a description of the several strata it is proposed to commence with the uppermost, and to proceed in the order of the table; before, however, entering upon the regular strata, it will be proper to take some notice of those superficial deposits which frequently cover them up, and occupy considerable portions of their surface; we have therefore to begin with alluvium or alluvial deposits. These are of limited extent in our islands, owing to the small scale of our rivers. They consist of silty and muddy matter brought down by rivers and deposited along the banks, or conveyed to their mouths or estuaries, where they form low shores and flats of rich soil near to and along the margin of the sea. Of these deposits we have instances throughout the course of all our principal rivers, but more extensively on the banks of their estuaries or tideways, and the neighbouring sea-shores, as those of the Trent, the Severn, and the Thames, which, whenever they are sufficiently raised by successive deposits, and subsequently drained and defended by embankments from the inroads of the sea, afford the richest pastures, and soils of almost inexhaustible fertility. The fens of Lincolnshire

and the marshes of Somerset form the most valuable grazing lands in England, an acre of which will fat an ox, or which under the plough sustain for a great many years successive crops of wheat, without any perceptible diminution of their fertility. The quantity of silty matter borne down by all rivers, especially in times of inundation, is very great. On the banks of the Parrot, near Bridgwater, this alluvial soil is dug out for making a peculiar kind of brick, and the deep excavations which are made in this way are soon filled up again by letting in the muddy water of the estuary. Such has been the effect of deposition, drainage, and embankment upon this low tract, that extensive herds of cattle now graze where, within the memory of history, the sea prevailed, and was navigated by small vessels to points at present many miles inland. In some parts of these moors there are extensive beds of peat, and wherever these are dug through for the purpose of draining, blackened timber and branches of trees, chiefly oak, are found in great abundance, which, as they are not attached to the soil, were in all probability brought down by ancient floods, and sunk in the then wide estuary. From these extensive flats the drainage is slow, as the water is discharged into the river by what are called regurgitating valves, which close when the tide rises, to prevent the water flowing back upon the land; and the discharge is in some situations assisted by steam pumps. The means applied, however, in many parts are insufficient, as a considerable portion of these moors is almost constantly under water during the winter season. These alluvial tracts are indicated on Professor Phillips's geological map by a

watery streak stretching a considerable way inland from the margin of the sea on the east coast, from Flamborough Head to Lynn Regis, in Norfolk, and from Wells to Bridgwater, on the Bristol Channel; also at the mouth of the Thames, and other places of less extent. Beneath the water these silty deposits in the estuaries of great rivers form shoals, which by their continual shifting endanger the navigation.

Another kind of deposit is in progress upon our sea-coasts, which may be called marine alluvium. This consists of sands and pebbles which are washed up by the sea upon some of our coasts, and which sometimes block up harbours and interrupt navigation; a remarkable instance of which occurs at the back of the Island of Portland, where the sea has thrown up an immense bank of pebbles, called the Chesil Bank, which, being in advance of the coast, and extending parallel to it for many miles, forms a narrow inland channel. In such cases the sea raises a rampart against its own violence and encroachment. Along the north coast of Devon and Cornwall at different places as far west as the Bay of St. Ives, calcareous sands are washed up by the sea and blown far inland, and in some places, as at Hayle and Perranzabulo, form high downs or hills along the coast. At the latter place a church was covered up and lost sight of for centuries; houses also were buried, and a pot of coins was dug up on a spot once inhabited. This sand, which is formed chiefly of comminuted shells and coral, consolidates into stone by the infiltration of stony matter dissolved in water; and the stone thus produced is so compact as to serve for architectural purposes, and has been used for

building a church. Though these sands are so destructive when they invade the country, they are nevertheless very beneficial under the control of man; as when they are dug below the high-water mark they prove very fertilizing to the adjoining land in the interior, and vast quantities are annually carried away for the purposes of agriculture. At Padstow these sands are said to be the richest in carbonate of lime, of which they contain about eighty per cent., and are conveyed inland by a railroad principally laid down for that purpose as far as Bodmin, while the same motive gave rise to the scheme of a canal from Bude harbour to the Tamar. On the south, near Helston, the terrific waves which roll into Mount's Bay have worked up a high mound of sand, and blocked up Loo Harbour, as it is yet traditionally called, though it now forms an inland lake of fresh water, which sometimes rises so high as to require to be discharged by cutting a trench across the bar of sand. Blown calcareous sands invade other shores than those of England. In the Bay of Biscay large tracts of country are covered by them, and Sir H. T. De la Beche says that forests, houses, and cultivated lands disappear beneath them. Many villages mentioned in the middle ages have been covered, and in the department of Landes alone, ten are now threatened with destruction. One of these villages has been striving for twenty years against them, and one sand-hill more than sixty feet high may be said to be seen advancing. It has been said that these downs advance at the rate of sixty or seventy feet per annum.

CHAPTER V.

THE TERTIARY STRATA.

The Tertiary Strata of England—The distinctive character of the Fossil Organic Remains from those of the Secondary Strata—Foreign localities of the Tertiary Formations, and the very remarkable organic remains found in them—General nature of the structure of the Tertiary Strata.—The newer Tertiary beds of England—Ancient superficial deposits, or diluvium; causes which produced them—Drifted Boulders—Counties over which these deposits are partially spread—Materials of which these deposits principally consist; the various situations of them in England, and some foreign localities, and the organic remains they contain—Enormous quantity of the Fossil Bones of Elephants discovered in the diluvium of Siberia.—Norwich Crag, character and extent of—Fresh-water beds of the Isle of Wight.—Bagshot Sand, its general character and extent—Sarsen Stones, or Grey Wethers—Those of Avebury and Stonehenge—Agricultural character of the soil, and means of improvement.—London Clay, general nature of—Sinkings for Water in—Mineral character of—Organic remains contained in—Depth and extent of—Agricultural character—Economical uses of the materials afforded by.—Plastic Clay Formation—General character—Organic remains—Extent—Sections of, afforded by sinking for Water in—Descriptions of, in the Isle of Wight, Alum Bay—Valuable materials afforded by the Plastic Clay—Agricultural character of, and means of improvement—Conglomerates of Hertfordshire, Somerset, and Devon.—Section of the Tertiary beds of the Paris basin, and the great variety of Fossil remains contained in them.—French Burrs or Millstones.—Tertiary deposits of South of Europe.

THESE strata include all those which are more recent than the chalk, upon which, in England, they are deposited in two distinct basins, one of which is called the London and the other the Hampshire Basin; but we may sometimes speak of the separate members of these strata without reference to the particular basin in which they are found.

This series of strata is remarkable for the great difference which exists between the fossil remains they contain, and those of the chalk upon which they repose. Almost all the older forms of organic life contained in the latter, the last of the secondary strata, disappear, and are supplied by others. With one or two very doubtful exceptions, the remains of the more perfect land animals are not found in the secondary strata, but these, though of species now extinct, appear in the tertiary, and very abundant in certain localities, some of them being of gigantic dimensions. The English tertiary deposits are chiefly confined to the localities above mentioned, of which we propose to give a particular description. They occur also in many parts of the Continent; in France, Germany, Austria, North and South Italy, Sicily, also in Western Asia, the Caucasus, and India. They appear to have been formed both in fresh and salt water; the former containing, the remains of land animals and birds, above alluded to, with the shells of fresh-water Mollusca; and the latter, immense quantities of marine shells, many of which, in the newest deposits, correspond with those living in the adjoining seas.

The older tertiary formation of England contains fossil wood, the seeds of extinct plants belonging to warm climates, remains of serpents of large size, and also turtles. In one of the subordinate beds of this formation beneath Paris, immense numbers of the bones of extinct quadrupeds and birds are found. In the newer tertiary are found numerous bones of elephants and other large animals, amongst which are those of the ox, horse, and deer, which are so abundant in Norfolk that

the stratum containing them has been denominated by Mr. Charlesworth, the Mammaliferous Crag. In one of the beds of this series on the Rhine, at Eppelsheim, more than thirty species of mammalia have been discovered, and amongst them the *Dinotherium*, the largest of terrestrial animals, and equally remarkable for its peculiar anatomy; its length is calculated to have been at least eighteen feet. In India, at the foot of the Himalaya, there exists an extensive tertiary formation of more than 200 miles in length, and 3,000 feet above the level of the sea, containing abundant fossil remains of various tropical animals, corresponding with some of those found in the basin of Paris; and associated with them are those of the giraffe, the hippopotamus, the horse, the camel, the antelope, and the monkey; and also a fossil tortoise, of gigantic size, measuring nearly twenty feet over the curve of the back. By the zeal and enterprise of Captain Cautly and Dr. Falconer, many specimens of the above fossil remains have been brought to England, and are now exhibited in the British Museum.

Though the strata of this series are for the most part of a looser and less consolidated structure than those of the secondary, they nevertheless afford compact limestones, as instanced in the building-stone of Paris; and Sir Charles Lyell says that a similar limestone of great hardness forms a stratum of several hundred feet thick near the base of Mount Etna in Sicily. Having taken this brief and general notice of the tertiary formations, we now proceed to give a more particular account of those of England.

NEWER TERTIARY STRATA.

ANCIENT SUPERFICIAL DEPOSITS.

Those superficial beds of drifted materials, consisting of boulders or large stones more or less water-worn and rounded, with pebbles, gravel, sand, and clay, which in many places cover up and conceal the regular strata, are commonly called *detrital* deposits, *drift*, or *diluvium*, because they consist of the fragments which have been torn away from their parent strata by the violent action of moving waters, and transported in mingled confusion often to very great distances. Impelled by such forces, large boulders have been transported from the Cumberland mountains and driven, not only across plains, but over intervening hills of considerable elevation, and spread upon the land to the south as far as Bridgnorth in Shropshire, more than 130 miles from their parent rocks. In many other places the same action has taken place, and the drifted materials, consisting of the detritus or fragments of most of the British strata, have been transported from the north and spread over portions of the eastern and midland counties, including Norfolk, Suffolk, Cambridge, Bedford, Huntingdon, Essex, and Middlesex. These materials consist of clay intermingled with fragments of various rocks, and beds of sand and gravel sometimes overlaid with the flinty gravels of the south derived from the destruction of the chalk formation and plastic clay, such as that which partially covers the London clay and extends towards the west.

These drifted beds are not only found in valleys

and on open plains, but also on elevated platforms divided by deep and abrupt valleys from the strata which produced them, so that they must have been deposited before the valleys were scooped out which now separate them from their obvious and known source. We may mention, as instances, the gravels which occur on the insulated hills of Derbyshire, and the detritus which extensively covers the middle oolites of Oxfordshire, as at Bagley Wood, containing fragments of the strata from the chalk to some of the oldest of the British series. Pebbles of chalk-flint are found upon the summits of the hills around Bath, though divided from the nearest chalk in Wiltshire by abrupt valleys of some hundred feet deep.

Diluvial beds cover a large portion of the central and northern plains of Europe and Asia, and in North America they occupy extensive tracts from the Alleghany Mountains to the Atlantic, and also in the great valley of the Mississippi, all testifying the great modification the surface of the land has undergone, and for beneficial purposes, as the soils these deposits afford are generally fertile, and, from the mingled materials of which they are composed being easily wrought, are well calculated to reward the labour of cultivation.

In these beds of transported materials are found buried the fossil remains of large extinct quadrupeds mixed with others of species now living. These remains are discovered in the gravels of England and in caverns, such as Kirkdale and others before mentioned; and it is remarkable, that the greater part belong to species, the corresponding families of which are now only found within the limits of the torrid zone, or in very hot

climates; such as the tiger, hyena, elephant, rhinoceros, hippopotamus, &c., indicating, therefore, a great change of climate since they were the inhabitants of the forests and plains of England.

It was at one time supposed by geologists that these diluvial beds were all the effect of one great catastrophe; but this opinion has given way to more attentive observation, from which it is now generally concluded, that they have been produced by causes more or less local, acting at different periods; some, perhaps, while a large portion of the strata which they cover were yet under the water; and others by a great and extensively-prevailing inundation after the surface had been long inhabited by animals whose remains we now find buried in its spoils.

The numerous deep hollows cut through the nearly horizontal strata, which are called valleys of denudation, attest the depth and force of the currents which produced them, and the enormous quantity of rock and earth they removed. Though in many instances the drifted materials are brought from great distances, the diluvium of different situations consists for the most part of the blended materials of the less remote and neighbouring strata; and as they consist of gravel, sand, clay, and calcareous matter, they generally afford deep and fertile soils, varying in quality according to the prevalence of the strata which have furnished the materials, and the consequent different proportions of each.

The depth of these deposits is sometimes very great. Von Wrangel states, that on the banks of the Kolyma, a river of Siberia, that flows into the polar sea, the cliffs, about 200 feet high, consist

entirely of sands and gravels, forming a conglomerate, or breccia, containing the bones of elephantine animals, and the whole mass is cemented together by frozen water. The same traveller also mentions, that at the Lochou Islands in the same northern sea, and beyond the 70th degree of latitude, bones mingled with the tusks of elephants are so exceedingly abundant, that large cargoes have been brought away, without any apparent reduction of the quantity.



IRISH ELK.

THE CRAG FORMATION.

The Norwich Crag chiefly consists of shelly beds of sand and loam, containing a few land and freshwater and many marine shells, with very numerous remains of mammalia imbedded in a regular stratum, as seen in the neighbourhood of Norwich, and at Southwold in Suffolk. This portion of the crag extends from Dunwich through the interior of Norfolk, nearly to Cromer on the north coast, in length about thirty miles, with a medial breadth of about five miles. Another portion of the crag

(named coralline) forms the estuary of the Stour in Suffolk, along the coast to Aldborough, with an average breadth of about ten miles. It consists of beds of sand, gravel, and blue or brown marl, with imbedded shells, for the most part broken, and sometimes very much reduced. In some parts it presents a soft stratified rock, consisting almost entirely of corals and sponges. Between Dunwich and Yarmouth are seen alternations of sand and shingle, of more than 200 feet in thickness, destitute of fossils. A third portion, the red crag, from the ferruginous character of its shelly sands, occurs chiefly at Walton, in Essex. In other parts of Norfolk and Suffolk, but superior to the crag, occurs an enormous mass of more than 300 feet thick, of sand, loam, and clay, containing bones of terrestrial quadrupeds and drift-wood, sometimes regularly stratified, at others confusedly blended with chalk and flints, and fragments of older rocks, septaria (cement stones), and fossils of the oolite series. Such is the description given by Sir Charles Lyell, who says that the whole presents a very confused appearance and blended character. Fresh-water formations of limited extent overlie the crag, consisting of loam, containing fresh-water shells. The crag forms in Norfolk and Suffolk soils of fertile character, which are highly cultivated. The district affords but little water, but it is thrown up when the porous strata are penetrated to the underlying London clay.

THE OLDER TERTIARY STRATA.

FRESH-WATER BEDS OF THE ISLE OF WIGHT.

Headon Hill, in the Isle of Wight, exhibits two beds deposited by fresh water, as indicated

by their organic remains, with an intermediate bed of marine origin. The upper fresh-water bed is covered by alluvium, which forms the summit of the hill. It is composed of a yellow or white marl, in some parts sufficiently compact and calcareous to serve for building-stone; it contains crystallized carbonate of lime in a radiated form, and abounds in fresh-water shells without any admixture of those of the sea. Many detached portions of the stratum occur in other places in the island, and numerous blocks of it are found in the soil about Cowes, Bembridge, and Binstead; and in the neighbourhood of Calbourne and Thorley, the quarries of it afford an excellent building-stone. Beds of sandstone and clay rest upon this stratum of marl at Headon Hill, and there are some beds of calcareous matter of great density and compactness, resembling stalagmite or travertin. This fresh-water formation is separated from another beneath, called the lower fresh-water bed, by a stratum of marine sand, containing some marine and estuary shells, (Colwell Bay.) The lower fresh-water bed consists of a series of sandy, calcareous and clayey marls, with some brownish coaly matter; some of these are composed almost entirely of fragments of fresh-water shells. There is, however, considerable difference in the quarries opened in this deposit. The following section of Binstead quarries is given by Conybeare and Phillips:—

	FEET.	IN.
1. On the summit, blue clay.		
2. Limestone, composed of coarse fragments of fresh-water shells	2	0
3. Do. the fragments being less coarse	4	0
4. Do. still less	2	0
5. Do. do.	1	6

	FEET IN.	
6. Siliceous limestone	1	6
7. White shell marl	0	10
8. Siliceous limestone	0	6
9. Sand	0	8
10. Siliceous limestone rag.	0	6
11. Sand	50	0
12. Blue clay of uncertain depth.		

According to the above geologists, and the late Mr. Webster, the whole of the north side of the Isle of Wight appears to belong to the fresh-water formation, though very much broken and difficult to trace. The limestone, though extensively worked in former times for building materials, is now but little resorted to for that purpose. Fresh-water beds occur on the opposite coast of Hampshire, which, according to Mr. Webster and Sir Charles Lyell, are equivalent to the lower beds of the Island, above described.

THE BAGSHOT SAND.

This stratum consists principally of siliceous sand and sandstone, without cement, and occasionally including beds of marl or brick earth. These sands are white, yellow, and sometimes of a darker colour and ferruginous, and associated with beds of flint pebbles or pebbly sand. A white sandstone of this formation was used in building the more ancient part of Windsor Castle. The Bagshot sand not only occupies the extensive sterile space called Bagshot Heath, but Frimly and Purbright heaths, and other places of the south; it also caps the heights of Hampstead, Highgate, and Hornsey, and extends northward to Finchley. *To the south of the Thames it is seen near Egham,*

extending towards Guildford, and occupies a part of Windsor Park. It seems probable that this sand once occupied a greater space, and extended far to the west over the chalk, where the only remains of it are seen in the blocks called sarsen stones, and grey wethers of Wiltshire, of which the Druidical circles of Stonehenge and Avebury are formed. These blocks lie upon the slopes of the chalk hills, as well as in the more level parts of the country, more or less imbedded in the soil, in some places so numerous as to resemble at a distance a reposing flock of sheep. We were informed by a peasant in the neighbourhood of Avebury that the plough often strikes upon these stones which lie beneath the surface.

Casts of shells are found in the sands of Bagshot Heath, and the marls which contain much green sand afford also fossil shells.

The agricultural character of this stratum is very unfavourable, as the sands are for the most part very arid and sterile, and therefore have undergone but limited improvement; and where not occupied by plantations, are generally abandoned to the wild and scanty productions of nature. Were the burdens of agriculture less heavy, and the population at the same time more numerous even than at present, hopeless tracts might be rendered tolerably productive, as the underlying stratum of clay, and the surrounding country, offer the means of improvement. Water can only be obtained by sinking into the London clay beneath.

THE LONDON CLAY.

This formation is so called from its being the general substratum of London, though partially covered with beds of gravel and sand. It consists of a deep mass of yellow and blueish, or brown clay, sometimes approaching to red, often containing sufficient calcareous matter to effervesce with acids, which gives it in a certain degree the character of marl; it also contains calcareous concretions in the form of nodules, called septaria (cement stone), with occasional beds of sandstone. The London clay is of various thickness, being, one mile east of London, only 70 feet, while at St. James's it was found to be 235 feet; at Wimbledon it was not sunk through at 530 feet, and at High Beach 700 feet. The following account of sinkings in this stratum are given by Conybeare and Phillips:—

Section of a Well sunk at Twyford, near Acton, Middlesex.

	FEET.
1. Yellow clay	38
2. Lead-coloured clay, containing some fossil wood at 180 feet, and shales at 200 feet from the surface	170
3. Rock	2
4. Sand and clay with pebbles	
5. Variegated clay, red, blue, and black . . .	32
6. Sand and water—thin	
7. Clay	

Section of a Well at White's Club House.

	FEET.
Blue Clay	142
Red Clay	93
	235

Water rose to about 45 feet from the top.

Section in Regent's Park.

	FEET.
Blue clay	140
Red clay	42
	182

Section of a Well sunk in Swallow Street, Westminster.

	FEET.
Gravel and loam	18
Yellow clay	12
Blue clay	130
Red clay	50
	210

The water rose in this well to within 60 feet of the surface.

At Kensington a section gave the following—

	FEET.
1. Vegetable mould	
2. Flint gravel	10
3. Lead-coloured clay	300
4. Oyster-shells	3 to 5

This clay contains selenite, or crystallized sulphate of lime, and sulphuret and phosphate of iron, which injure the water for domestic purposes. The septaria before-mentioned are dredged up in great quantities at the Isle of Sheppy, after having been worked out of the soft cliff by the sea; they are then calcined, pulverised, and packed in casks to supply London and other places with cement. They consist of clay, oxide of iron, and carbonate of lime; and are therefore called by the mineralogists argillo-ferruginous limestone. Nodules of this substance are frequently thrown up in digging wells and drains in London. The qualities of this excellent material are well-known in its various uses of coating and ornamenting buildings, and the construction of sea-walls and other fabrics under water; for which

purpose it is generally mixed with a greater or less proportion of sand; but in the construction of the Tunnel at Rotherhithe, it was used without any mixture.

The London clay is very rich in organic remains: fossil shells in high preservation, and of great variety and beauty, occur in abundance, with fish remains, and some species allied to the crab and lobster; also fossil wood, often preserving the woody and fibrous structure, but generally black, as if partially charred, and in many specimens perforated by, and containing the cast of an animal resembling the *Teredo navalis*, or Borer of our present seas. But the most remarkable remains discovered in this vast deposit of ancient mud, are those of seeds, of which no less than 700 different kinds have been found, all of extinct species, which appear to have been the production of a tropical, or hot climate, and some resemble the seeds of cocoa-nuts, and others of spices.

The geological map of Professor Phillips represents this stratum, with the plastic clay beneath, from which it is difficult to distinguish it, and the crag, and Bagshot sands, that overlie it, as extending from Aldborough, on the coast of Suffolk, to near Hungerford, in Berkshire; which, with the exclusion of some outlying patches along the north coast of Kent, may be nearly traced by the sea-coast of Suffolk and Essex, as far as Gravesend; and thence, after crossing the Thames, by the towns of Croydon, Epsom, Basingstoke, and Kingsclere on the south, to its extreme point on the west, at Hungerford; from thence, returning, the line runs nearly east to Reading, from whence, in a direction more or less north-east, it passes near:

the towns of Windsor, High Wycombe, Watford, St. Alban's, to Harlow, Thorpe, Colchester, Ipswich, Woodbridge, on to the sea-coast again at Aldborough: thus occupying the whole of Middlesex, with a considerable part of the counties of Suffolk, Essex, Kent, Surrey, Berks, Hertford, and Hants. The above description includes only that portion of these strata which rest upon what is called the chalk basin of London. In the Hampshire, or Southampton basin, these deposits occupy the southern parts of Sussex, Hants, Wilts, and the south-east of Dorset; extending from near Brighton on the east, along the coast, including a portion of the Isle of Wight, to the south of Poole, by Swanage, inland to Dorchester; from the latter place, the line passing by Lyme Regis and Cranbourne, to its extreme limit beyond Salisbury; thence, turning to the south-east, it passes considerably to the north of Romsey and Southampton, by Chichester and Arundel, to its termination on the coast, west of Brighton.

The London clay nowhere reaches a great elevation, its highest point being near High Beach, Essex, where it is 759 feet above the level of the sea. Langdon Hill, also in Essex, is 620 feet; Shooter's Hill, in Kent, 446, and Hampstead and Highgate, on the north of London, about 400 feet above high-water mark.

Water is obtained in and about London by sinking through the superficial gravel, which is seldom many feet deep, and from such shallow sinkings the public or street pumps are generally supplied. But when larger quantities are required, as for the use of brewers and distillers, the sinkings or borings are continued through the London

clay to the sands or gravels of the Plastic clay beneath, and in some instances to the chalk, from which copious supplies of excellent water are obtained. We have before alluded to the Artesian process adopted for this purpose.

With regard to the agricultural character of this formation, it has the usual defects of clays, both in wet and dry weather, driving up before the plough when in a moist state, and opening with wide cracks during droughts. It is, however, made very productive under spade-culture, aided by a plentiful supply of manure, particularly in the immediate neighbourhood of London. With the exception of the large market-gardens surrounding the metropolis, nearly the whole of Middlesex, and parts of the adjoining counties, are devoted to grass, for the supply of milk and hay. The most productive soils, both in pasture and under garden culture, are afforded by the alluvial flats on the banks of the Thames, and the gravels are turned to good account, both as garden and nursery grounds.

The situation of London upon this deep bed of clay, is perhaps the most favourable that could be selected, as it affords an inexhaustible supply of brick earth,* a building material the best adapted to domestic architecture, with an almost equally convenient supply of lime and cement; the former from the neighbouring chalk, and the cement from the mass of clay itself. By the ingenious application of the latter, the dusky monotony of long ranges of brick buildings has given place to the various pleasing styles of architectural design,

* A great portion of the brick earth is derived from the superficial beds of clay and loam which overlie the London clay.

without incurring either the expense or dampness of massive stone buildings.

THE PLASTIC CLAY.

This is the lowest member of the English tertiary formations, or rather of the older tertiary, or Eocene, under which head it is now associated by some of our most eminent geologists with the London clay above it; indeed, in some cases it would be difficult to draw a line between them which would not be considered an arbitrary and groundless distinction. There are, however, certain general characteristics which appear to justify the separation, or at all events to entitle them to a separate consideration.

This stratum, or as it may now be called, division of the London clay, consists of numerous alternating beds of sand, clay, and pebbles. It has received its name from its resemblance to a similar deposit in the Basin of Paris. The sands are of almost every colour, which are beautifully exhibited at Alum Bay, in the Isle of Wight, where this stratum being thrown upon its edge, presents the varied-coloured sand in distinct vertical stripes, from a pure white to a deep red. The white sand is extensively used for glass-making in the northern manufactories. The clays also are of different colours, and according to their quality are denominated fire, brick, pipe, and potters' clay; the two latter are dug in the Isle of Wight, but the chief supplies for the potteries of Staffordshire are obtained from the neighbourhood of Poole, in Dorsetshire. Fuller's earth is stated to be found in this stratum near Reading.

Beds of brick and potters' clay occur in detached masses on the summits of the chalk hills of Wiltshire and Dorset. The beds of pebbles consist of chalk flint, small and exceedingly rounded, or water-worn, a deep mass of which may be seen at the edge of Blackheath which overlooks Greenwich to the west. Iron pyrites occurs in the white clay of Poole and of Alum Bay; in the latter place so abundantly as to have been used formerly for the manufacture of alum; selenite and fibrous gypsum are also found in the same locality in this clay, and at Newhaven, on the coast of Sussex.

The organic remains of the plastic clay consist of various shells and the teeth of fishes, corresponding nearly with those of the London clay, with imperfect wood-coal, exhibiting, in some cases, the branches and leaves of plants which appear to have been the produce of a warm climate. At Woolwich, near London, these beds contain shells belonging to fresh-water genera.

In describing the extent of the London clay, we have given the extreme boundary of that and the plastic clay together, in both the London and Southampton basins, the water-limits being generally occupied by the latter, which covers the largest space on the western portion of each basin.

There are two means by which we obtain a knowledge of the masses of materials of which the strata are composed; the first afforded by the convulsions of nature and the action of water, by which the edges of the strata are laid bare to our inspection, and the latter by sinkings made in mining operations, and for the purpose of obtaining water. Both these means of inspection are

afforded in the plastic clay; but the latter more abundantly than in many other strata, from the frequent perforations of it to supply the great demand in and about London; an account of many of which is given in that instructive work, the “*Outlines of Geology*,” by Conybeare and Phillips, to whose labours English geology is much indebted. The following particulars of sinkings are derived from the above authority, which show the very mixed and alternating character of the materials of this formation or deposit, and which, together with that which is open to the day in other parts, manifest the great diversity of the beds of which it is composed in different localities.

Section afforded by the Sinking of a Well at Liptrap and Smith's Distillery, one mile east of London, the surface of the ground being 36 feet above high-water mark.

<i>Alluvium</i> . .	{	7 feet of earth.
	22	„ gravel and sand, containing land-springs.
<i>London clay</i>	77	„ blue clay.
	5	„ sand; a spring.
	6	„ soft blue clay.
	2	„ a kind of marl, yielding some water.
	9	„ yellow clay.
<i>Plastic clay</i> .	12	„ blue clay intermixed with gravel.
	9	„ hard brown clay ditto.
	12	„ green-coloured sand and gravel.
	12	„ small gravel and sharp sand; a spring.
	1½	„ green-coloured clay.
	85½	„ light-coloured sand.
	2	„ flint and chalk—mostly flint; a spring.
	36	„ hard chalk and flint.
	23	„ ditto, ditto.
	62	„ ditto, ditto; a spring.
	37	„ ditto, ditto; no water.
	370	

After sinking a well to the depth of 106 feet, the remainder, 264 feet, was bored with an eight-

inch auger; the water rose to within 36 feet of the surface, and the springs from the chalk yielded the greatest quantity.

Section afforded by Sinking a Well at Mr. Joseph Foster's, at Bromley, near Stratford-le-Bow, Middlesex.

<i>Alluvium</i> . .	18 feet of loam, clay, gravel, and sand.
<i>London clay</i> 44	„ blue clay; water beneath.
2	„ blue clay.
1	„ clay; sand and shells mixed.
4	„ gravel, sand, and shells.
4	„ fine sand.
9	„ blue and yellow clay.
4	„ sand and shells, with large lumps of pyrites; a spring of soft-water sufficient to fill a 2½-inch pipe.
9	„ blue clay, with abundance of broken shells, some resembling oysters.
	1 foot of solid limestone.
	22 feet of sand and small rounded pebbles, like those at Blackheath.
2	„ blue clay, very hard and firm; copious springs of water, which threw much fine white sand into the pipe.

120

The different beds of the plastic clay are remarkably exhibited in the disturbed and vertical position of them in the Isle of Wight, and are thus described in the work above mentioned:—
 “The stratum next on the north to the nearly vertical chalk of Alum Bay is chalk-marl, then succeed green, red, and yellow sand, together about 60 feet in thickness, and in the same position; and afterwards a bed of dark-blue clay, about 200 feet thick, containing much green earth and nodules of dark-coloured limestone, enclosing a few fossil shells. Next follows a vast succession of beds, of various colours, 321 feet in thickness; next to which, and in the middle of the bay, is a

very numerous succession of beds, which contain a large proportion of pipeclay, of various colours, white, yellow, grey, and blackish, which alternate with beautifully coloured sands. The clay is sometimes in beds several feet in thickness, without any admixture, and sometimes in laminæ not a quarter-of-an-inch thick, with sand between them, the whole being about 543 feet in thickness. Near the middle of these latter beds are three beds of a sort of wood-coal, the vegetable origin of which is directly indicated by the roots and branches still to be observed in it; it sometimes splits into irregular layers, in the direction of the beds, and the cross fracture is dull and earthy. It burns with difficulty, and with very little flame, giving out a sulphureous smell. About 150 feet on the north are five other beds of coal, similar to the preceding, each a foot thick. On the north of the whole of these beds are several layers of large water-worn black flint pebbles, imbedded in deep yellow sand, to which succeeds a stratum of blackish clay, with much green earth and septaria, 250 feet in thickness, and analogous to the London clay. These strata extend quite across the island, in a vertical position, keeping parallel to the chalk, and appearing again at the White Cliffs Bay, on the east end, where, however, they are much concealed by grassy slopes. The sands, marls, and clays are of every possible variety of shade and colour, giving to the cliff in Alum Bay, which is about 200 feet high, when viewed at a little distance, a very beautiful appearance. The number and variety of these are endless; they may be compared to the stripes on the leaves of a tulip, and are almost equally bright.

On cutting down pieces of the cliff, it is astonishing to see the brightness of the colours, and the delicacy and thinness of the several layers of white and red sand, (some of which do not exceed the eighth of an inch,) shale and white sand, yellow clay, and white or red sand, and, indeed, almost every combination of these materials. The forms of particular parts of this cliff, when viewed near, and from the beach, are often of the most picturesque and even sublime kind, resembling the weather-worn peaks of alpine heights. The fact is, that the weather has worn away the softer parts, leaving the more solid sharp and pointed."

From what has been stated above, it will appear that the plastic clay formation affords valuable materials for economical purposes; as sands for glass-making, and clays for bricks, pottery, and pipe-making; but its agricultural character, as might be expected from the nature of the different beds, is, upon the whole, unfavourable, as it presents on its surface the two extremes of a very loose sand, and a very stiff, intractable clay. Even fir-trees thrive but indifferently upon the former, as in the tract round Poole; but the clay soil, where the stratum thins out, is improvable by the chalk beneath, which in many places is sunk into, and used as a top-dressing with great effect.

The siliceous conglomerate (pudding-stone) of Hertfordshire, of which large blocks are scattered here and there over the chalk, and even as far west as Somerset and Devon beyond its present limits, consists of rounded pebbles of this stratum, united by a siliceous cement, and affords another indication of the extensive destruction of this formation.

The tertiary deposits of the Paris basin, which

have been before alluded to, differ very widely in mineral character from those of England, as will be seen by the following tabular statement of them by Sir Henry De la Beche, commencing with the lowest bed.

- | | |
|-----------------------------------|--|
| 1. <i>Fresh-water formation</i> | { Plastic clay.
Lignite (wood-coal).
First sandstone. |
| 2. <i>First marine formation</i> | { Calcaire grossier (coarse limestone).
Siliceous limestone. |
| 3. <i>Fresh-water formation</i> | { Gypsum, with bones of animals.
Fresh-water marls. |
| 4. <i>Second marine formation</i> | { Gypseous marine marls.
Upper marine sands and sandstones.
Upper marine marls and limestones. |
| 5. <i>Fresh-water formation</i> | { Mill-stones with shells.
Shelly mill-stones.
Upper fresh-water marls. |

These beds contain a great quantity of organic remains; but the most remarkable in this respect are the gypsum beds, in which are imbedded the fossil bones of a great variety of extinct animals, including quadrupeds, crocodiles, birds, fish, and shells, of which a particular account has been given by the late Baron Cuvier. The siliceous mill-stones are imported into this country under the name of French burrs, and are an extensive article of commerce. The tertiary deposits occupy a considerable portion both of the north and south of France; they surround the bases of the Alps, and in Italy form the advanced and lower ridges of the Apennines through their entire length, and cover a considerable portion of Sicily, where they are of great thickness and elevation. Sir Charles Lyell, in describing the tertiary formations of Sicily, states that one member of the newest of them, the great limestone, is no less than eight hundred feet thick.

CHAPTER VI.

NEWER SECONDARY STRATA—THE CRETACEOUS FORMATION—THE WEALDEN AND UPPER OOLITES.

The Cretaceous Formation—The mineral character and contents of the Chalk Strata—Range and extent—Superficial appearance—Extensive denudation, and destruction of—Elevation and thickness of the Strata—Economical uses of—Organic Remains—Agricultural character—Water Springs.—The Greensand—Extent—Division of—Mineral contents—Quarries of Scythe-stones and Building-stone of the Blackdown—Elevation—Organic Remains—Agricultural character and means of improvement—Water Springs—Thickness of the Strata.—The Wealden Formation—Wealden Clay—Mineral character—Petworth Marble—Agricultural character—Water—Slips in the Isle of Wight—Scenery of—Thickness of the Stratum.—Hastings Sand—Mineral character—Organic Remains—Saurians—The Iguanodon discovered by Dr. Mantell—Agricultural character—Valley of the Weald—How produced—Thickness of the Stratum.—Purbeck Beds—Structure and mineral character—Organic Remains—Fossil Shells, and impressions of Fish—Shell Marl—Purbeck Marble—Building and Paving-stone—Fresh Water—Character of these Strata.—The Oolitic System—Character and extent—Portland Quarries—Dirt Bed and Fossil Trees.—Kimmeridge Clay—Mineral character and contents—Imperfect Coal—Organic Remains—Saurians—Ammonites and Belemnites—Thickness—Agricultural character, and Water.

THE chalk, which forms the uppermost member of this group, is one of the most remarkable and extensive of the British strata, and consists almost entirely of carbonate of lime, with occasional bands or beds of black flints. The deposition of this vast mass of calcareous matter appears to have been principally effected by the instrumentality of very minute microscopic shell-fish, so exceedingly small that Ehrenberg computes that one cubic inch of chalk contains at least a million of them, and that, when diffused through water, *they are* a long time in subsiding, and are with

difficulty separated from it. When a coat of whitewash made from chalk is examined with a powerful microscope, it exhibits a mosaic-work of these minute shells. The flints also appear to have had a similar origin, and to be derived from animalculæ with siliceous shells, which have become consolidated by segregation round other substances, generally sponges, which served it as a base. These bands of flints may be seen along the face of the chalk cliffs on the south coast of Kent, and are mostly confined to the soft, or upper bed of the chalk. Though the tertiary strata, previously described, occupy a considerable portion of the surface of the chalk, a much larger extent remains uncovered. From Flamborough Head, on the coast of Yorkshire, it extends, in a south-easterly direction, to the Wash of Lincolnshire; commencing again on the north coast of Norfolk, it proceeds in a south-west direction, and occupies a considerable portion of the counties of Norfolk, Suffolk, Cambridge, Hertford, Oxford, Berks, Wilts, and Dorset, to the channel near Weymouth. From the great central space of Salisbury Plain, it takes an easterly direction, by Andover, Alton, Guildford, Reigate, Wrotham, Rochester, to Ramsgate, Deal, and Dover, on the east coast of Kent. In another direction, from Salisbury Plain, it proceeds, by Winchester, Arundel, and Lewes, to Brighton, Newhaven, and Beachy Head, on the channel. It also passes through the centre of the Isle of Wight, from the Culver Cliffs on the east, to the White Cliffs and the Needles at the western extremity, occupying a large part of Hampshire, and greater or less portions of Surrey, Sussex,

and Kent, by those two southern divisions of its course. Chalk also occurs in the north of Ireland.

The surface of the chalk presents frequently throughout its course bold eminences of rounded form, and steep escarpments or acclivities, while its extensive surface is everywhere more or less deeply furrowed; and these furrows or valleys extend beneath the plastic clay, as may be seen on the banks of the lower part of the Thames, when on the face of the cliff they are seen to be filled up by the sand, clay, and gravel of that formation. It is evident, therefore, that before the deposition of the plastic clay, the chalk had undergone deep erosions and extensive denudations from the violent action of water, which is further attested by the immense quantity of rounded chalk flint or chert pebbles contained in the stratum above it, derived from the cretaceous beds, of which the thick accumulation of gravel at Blackheath and Bexley are remarkable instances. This destruction of the chalk has taken place most extensively in the west, where the valleys cut deeply through it, as that of the Stour, in Dorsetshire. In this valley, through which the river flows, numerous lateral valleys, or hollows, descend, now destitute of water, but the depth of chalk through which they are cut attests the force of the torrents by which they were formed; and it is very remarkable that wherever these now dry valleys open upon the main one, the river recedes to the opposite side of the vale, and is often driven close under an abrupt cliff, evidently owing to the force of the currents which descended through the lateral valleys during the period when the great *work of destruction* took place, and diverted the

main stream from side to side, producing that winding course which the present feeble current is seen to pursue. Between the Marlborough Downs and Salisbury Plain the chalk has been extensively destroyed, and the great denudation forms the fertile vale of Pewsey. The slopes, or escarpments of the chalk hills, on either side are more or less abrupt, those on the north being the most lofty, forming the bold heights of St. Anne's and St. Martin's hills; and the prevalence of the chalk at one time over the intervening space is rendered evident by the outliers of chalk, or chalk marl, which at different points stretch far into the vale, the centre of which is greensand. This beautiful vale extends east and west, but on the south side a narrow valley opens, in which the Avon pursues its course to Salisbury and the south channel. Some outliers or detached parts of the chalk extend as far as Chard, in Somerset, and the valley of the Axe in Devonshire; and chalk flints are found on the summit of the Blackdown, overlooking the vale of Taunton Dean. The chalk attains very considerable elevations in different parts of its range. Welton Beacon, in Yorkshire, rises 809 feet above the level of the sea; Inkpen Beacon, in Wiltshire, is 1,011; and St. Ann's Hill, the highest point of the Marlborough Downs, is scarcely less; while the thickness of the whole of the beds of which it is composed has been variously estimated at from 600 to 1,000 feet. Near Dover the measure of these beds amounts to 620 feet; and at Handfast Point, on the coast of Dorset, they attain to 800 feet; but the vertical beds at the Culver Cliffs, Isle of Wight, are of much greater thickness.

The different portions or beds of the chalk formation vary considerably in their chemical and mechanical structure. The upper portion, or that which forms the surface of the larger portion of the chalk districts, consists of soft marking chalk, containing beds of flints of greater or less thickness, which are extensively raised for making roads; this chalk is nearly pure carbonate of lime, as much as 98 per cent., with a small portion of alumina and magnesia, and, according to Smeaton, when well burnt, makes as good lime as the hardest marble, and is that which is almost exclusively used for building purposes in London, supplied from the numerous kilns along the banks of the lower portion of the Thames. The next bed or stratum beneath is much harder, and contains fewer flints, of which it is sometimes almost destitute. This portion of the chalk is so firm as to be used for building stone, and in the neighbourhood of Dover is blasted and squared for building sea walls and other durable works. It was formerly used in the construction of churches, and the delicate ornaments in the ruins of some of them attest its durability; amongst others, the abbey at St. Omars, which is entirely constructed of chalk, retains all its beautiful ornaments in great perfection. The lowest portion of the chalk is of much softer consistence, containing a considerable portion of alumina, thus forming a chalk marl which graduates into the greensand beneath. The principal extraneous mineral matters in the upper chalk are flints and iron pyrites, with small portions of siliceous sand, from the latter of which it is never perhaps entirely free. In making *whitening*, the sandy particles are separated by

grinding the chalk and floating it with water, so as to allow the flinty particles to subside.

Besides the innumerable microscopic shells, which, as observed above, constitute a large portion of the bulk of the chalk, it abounds in others of a larger size and of great variety, with the remains of crustaceous animals, fish, sharks' teeth, and gigantic reptiles; but no remains of mammalia or the more perfect quadrupeds have yet been discovered; and it is a most remarkable fact that these fossil remains differ altogether from those contained in the tertiary strata above the chalk, and that no two species are common to both. Fossil plants are also found in the chalk, which, with the animal remains, appear to have been of marine origin. Fossil wood has also been discovered, penetrated with a boring shell-fish, after the manner of the drifted wood of our present seas. Sir H. T. De la Beche has given copious tables of fossil remains found in the chalk.

A large portion of the upper chalk districts is devoted to sheep pasture; and by the practice of the folding system, which prevails in the south of England, serves to enrich the adjoining arable land, and enable it to afford crops of great and uniform luxuriance. A considerable portion has, however, been brought under cultivation; and where it is covered with a hazel coloured soil, which is aluminous and flinty, good and even abundant crops are obtained, both of wheat and barley, by the aid of turnip culture and the sheepfold. The lowest portion, or chalk marl, produces strong wheat and bean lands bearing the heaviest crops; and when it blends with the sand beneath, affords soils of the most fertile character

for every kind of crop. Their great fertility is perhaps principally owing to their containing a considerable portion of phosphate of lime, which has recently been discovered in the beds at the base of the chalk in the neighbourhood of Farnham, and in the Isle of Wight throughout its whole length, where the marl containing this valuable substance is said to be from one to three feet thick. There is little or no doubt but similar deposits might be found along the base of other portions of the chalk, the discovery of which would supersede the expensive use of bones over a considerable portion of the neighbouring soils, and especially those of the greensand, and thus afford another instance of the benefit of geological science to the practice of agriculture.

Though the chalk districts are, for the most part, destitute of timber, and unfavourable to its spontaneous production, and therefore present an exposed and naked appearance, yet the beech thrives well, and often grows with great luxuriance, as may be seen in many places to the north and west of London, as at Tring and Henley, and some parts of Hampshire; and the Chiltern Hundreds, in Oxfordshire, are said to have been once covered with woods and thickets of beech, which harboured numerous banditti, and gave rise to the office of the Steward of the Chiltern Hundreds, now a mere pretext for vacating a seat in Parliament. There can be no doubt that if the extensive exposed tracts, such as that of Salisbury Plain, were judiciously planted with deep belts of beech, the value of the intervening land would be much enhanced by the *improvement* of the climate, and the shelter thus

afforded both to plants and animals. The deep trenching and planting such tracts would afford employment to numerous labourers when other occupation cannot be obtained, and would, at the same time, be one of the most provident applications of superfluous wealth.

The chalk, from its absorbent and porous nature, affords no water when sunk into, unless penetrated to a great depth, but it accumulates in the fissures of the lower portion, and copious springs of excellent water are thrown out at the base of many of the hills, where its downward progress is intercepted by the underlying chalk marl. The rivers which flow from the centre of Wiltshire to the South Channel, as well as the Kennet, which joins the Thames, derive their waters from this source. Abundant streams of water pour from the base of the chalk into Lulworth Cove; and the rivulets which supply the Wandle, in Surrey, have a like origin. These streams, which flow from the lower beds of the chalk, produce the best water meadows in England, and none excel those found along the course of the Kennet and the Avon, where irrigation is carried to great perfection, and produces astonishing crops of grass.

THE GREENSAND.

(Including the UPPER GREENSAND, GAULT, and LOWER GREENSAND.)

This formation extends, with but little interruption, from Haldon Hill, on the west of Exeter, and the Blackdown, in Devonshire and Somerset, to within a few miles of the Humber, accompanying and cropping out from beneath the chalk

through the greater part of its range on its western edge. It appears again from beneath the chalk at Folkstone, in Kent, and extends by Maidstone, Sevenoaks, and Godalming to near Alton, whence, trending southward and eastward, it continues by Petersfield, Medhurst, Steyning, and Lewes, to near Beechy Head, on the Channel. The greensand consists of two strata, separated by a bed of blue clay, or marl, called gault, containing numerous fossils; the sand is siliceous, and derives its name from green particles of silicate of iron, which are dispersed through it. Beneath the surface it forms a soft rock, in which sandy particles are united by a calcareous cement, sometimes containing beds and nodules of chert, veins of chalcedony, and masses of limestone, called Kentish Rag, of which the brown lime used in London for forming concrete is made. Chert and chalcedony occur more frequently in the west, as on the Blackdown, and the heights above the valley of the Axe, and Sidmouth, at which latter place beautiful pebbles of this kind bestrew the seashore from thence to Charmouth, and to which continual additions are made by the falling down of the greensand, which here caps the lofty cliffs of sandstone and red marl. The quarries of Blackdown furnish the valuable scythe stones of the south of England, and durable building stone is obtained in the same range, of which the Wellington monument, or tower, on that ridge is built. This stone when first taken from the quarry is quite soft, but soon hardens by exposure. Through the eastern counties the greensand is generally level, but on the west rises into bold *eminences*, as at Stourhead and Blackdown, in

Somerset and Devon, and the Pilsdon and Leusden Hills, in Dorset, which rise to seven or eight hundred feet above the level of the sea. The greensand contains in some places iron pyrites (sulphuret of iron), with occasional masses of other kinds of iron ore. The organic remains are very numerous, and nearly correspond with those of the overlying chalk, amongst which are several kinds of ammonites; and the other shell-fish are so numerous, that the quarries of the Blackdown alone, according to Conybeare, afford no less than 150 different species. These fossils are generally highly preserved as to their external form, frequently presenting a perfectly silicified and polished form of the original, with all its minutest points and angles. Silicified wood is sometimes discovered penetrated with borers.

The agricultural character of this formation is various. The more level lands of the eastern part of the kingdom possess considerable fertility, and afford some of the best turnip, potato, and barley soils in the south of England, as well as for market-gardening upon a large scale, for which it is admirably adapted, both by its warm colour and the facility with which it is cultivated. The fertility of this sand as it approaches the chalk, which it underlies, has been already noticed, which is, perhaps, partly owing to the very favourable mechanical mixture of the soil, but probably more to the beds containing phosphate of lime, which, as mentioned above, has been recently found at the junction of the sand with the overlying chalk. To the westward, where the greensand rises into bold elevations, as at the Blackdown, in Somerset and Devon, and where it is cut through by the valleys

which descend to the south, the soil becomes poorer and cherty, and for a considerable extent affords only poor sheep pastures, or is covered with heath.

Springs appear not to be abundant in this stratum, and the well-sinkers penetrate to a considerable depth for water; in some instances from 80 to 120 feet, where probably the water is sustained by the weald clay. The thickness of the greensand has been variously stated, but perhaps nowhere much exceeds 300 feet. All estimates of the thickness of strata must be received with considerable latitude, as in any one great variations will occur in different localities, partly owing to the degradation of their extremities, and partly to the irregularities of the strata upon which they rest; an approximation, therefore, is all that can be expected in giving the thickness of any of the strata.

MIDDLE SECONDARY STRATA.

THE WEALDEN FORMATION.

This formation, the next in the descending order to the cretaceous, consists of three strata of very distinct character, but all of fresh-water origin, as indicated by their fossil organic remains; viz. the Wealden clay, the Hastings sands, and the Purbeck beds. These strata, which are confined to the south of England, occupy the larger portion of Kent, Surrey, and Sussex, with a part of Hampshire, extending from the coast at Hythe, in Kent, westward nearly to Petersfield; and from Hastings, in a northerly direction, to beyond Tunbridge; there are also two detached portions,

one on the south-west coast of the Isle of Wight, and the other at the Isle of Purbeck, on the coast of Dorset. The thickness of the whole of this fresh-water deposit has been estimated at no less than 2,000 feet.

THE WEALDEN CLAY.

This is the uppermost member of the Wealden group, which appearing from beneath the greensand above described, surrounds and rests upon the Hastings sands, or iron sands of Tilgate Forest, except for a few miles on the coast, where the latter stratum forms the shore of the channel, from Ben Hill to Hythe, on either side Hastings. It appears also in the Isle of Wight with its accompanying sand, where it may be traced under the greensand, and was the cause of the remarkable landslip, which took place at Black Gang Chine in 1799.

This stratum consists of beds of dark-coloured clay, varying to blue marl of a somewhat friable texture, containing subordinate beds of a peculiar argillaceous limestone full of shells, which, from its capability of receiving a fine polish, and exhibiting great beauty both of colour and consistence, has, under the name of Petworth marble, been extensively used for ornamental purposes, and especially to form members of the clustered shafts of our cathedrals; it is, however, of so fragile a nature, as frequently to separate under the hands of the workman, and therefore is much less used than formerly. Some quarries are still kept open for this stone, near Kindford, and North Chapel, Surrey. The tenacious character, and consequent

stiffness and coldness of the Wealden clay, render it unfavourable to the operation and purposes of agriculture, and better adapted to the production of timber and underwood, but especially of oak. Draining, to get rid of superfluous moisture; burning, to render it more friable; and the mixture of the sands and chalk which lie on either side of this clay, offer obvious and practical means of improvement. The water which percolates through the incumbent greensand is thrown out by this retentive stratum, and on the south side of the Isle of Wight has produced, by the extensive and irregular slips it has occasioned, the wildest disorder and the most picturesque scenery, on the bold shores of that interesting island. The mixture of the subsiding sand and clay affords a favourable soil for the production of trees and underwood, which partially clothe the rugged features of the surface with a mantle of great beauty and variety, here and there revealing cottages and villas with their gardens and corn-fields. In the Weald of Kent, this stratum of clay is stated to be 300 feet thick, where its surface presents a broad vale, and no where rises to any considerable elevation.

THE HASTINGS SAND.

This portion of the Wealden group, sometimes called iron sand, occupies the extensive tract known by the name of Tilgate Forest. It is composed chiefly of sand and sandstone, with occasional beds of clay, marl, fullers' earth, and ochre. The sands are siliceous and of a brownish or red, and sometimes yellow, colour, and in places contain so *much* oxide of iron as to have been resorted to in

ancient times for that metal. In some parts the sandstone becomes a coarse conglomerate of pebbles, which is sometimes used as a building stone; fossil wood and thin beds of coal occasionally occur in this sand, which have led to unprofitable sinkings in search of coal in the neighbourhood of Bexhill, in Sussex.

The organic remains are numerous, including shells, fish, turtles, and five genera of Saurian animals. The iguanodon, a land animal of the lizard kind, the fossil bones of which were discovered by Dr. Mantell, appears to have been of the most gigantic proportions, as the separate portions indicate the length of the whole to have been from forty to seventy feet in length, by ten feet high. If we adopt the least of these dimensions, the animal to which these bones belonged must have very far exceeded in size the largest which now inhabit the earth. The fossil bones of birds have also been found in the Wealden sand, but no where have any remains of mammiferous quadrupeds been discovered.

The constitution of this stratum, and the freedom with which it can be cultivated, render it favourable to agriculture, and, under good management, give a general character of fertility. It is very favourable to the growth of wood, and derives its name from the forest which once covered it.

The valley of the Weald, bounded on either side by the chalk hills, the North and South Downs, except where it opens to the sea at Hastings, is supposed by some geologists to be an extensive denudation of the chalk which once covered the whole of this formation, and which evidently now overlies a portion of it; and the

elevation it has undergone along the centre, which causes it to discharge its waters in opposite directions, appears to favour the opinion. It is probable that the Hastings sands are about 500 feet thick, though upon this point no very reliable knowledge exists.

PURBECK BEDS.

These beds form the lowest members of the group, and consist of thin layers of imperfect shelly limestone, alternating with beds of slaty marl, having a total thickness of about 300 feet. The following description of these beds is given by that accurate geologist the late Mr. Webster.

The Purbeck stone consists chiefly of shells, partly whole and partly in a state of comminution, imbedded in calcareous cement, which is sometimes very pure and crystalline, and at others approaching to an indurated marl. These beds are separated by others entirely without shells, and also by layers of shells and marl, the shivering nature of which allows the stone to be quarried with much ease. It is thus obtained of various degrees of thickness according to that of the bed, and the whole hill consists of many alternations of thin strata. One of the uppermost of these beds yields the well-known Purbeck marble, employed in making monuments and the columns of Gothic buildings, which much resembles the Petworth or Sussex marble, but with the shells more perfect than in the latter. The other Purbeck beds furnish a good material for building, paving, and making water troughs. The workmen frequently discover in the beds of these quarries the

impressions of fish, with numerous fragments of bones, and sometimes entire fossil turtles.

The agricultural character of the soil of this formation is rather unfavourable, as it consists of marly clay, and is consequently cold and difficult to work. Considering the mechanical nature, and the organic remains contained in the Wealden group, Sir Charles Lyell concludes that these strata were deposited from the fresh water of a great river in the manner of the deltas in the estuaries and at the mouths of the great rivers of our present continents. The downward movement of the strata beneath, which allowed of the accumulation of beds of such depth as those which form the Wealden group and the incumbent greensand and chalk, and their subsequent elevation, with the consequent denudation of the chalk upon their surface, so as to produce the present actual condition of these strata, present some of the most interesting phenomena, which at every step of his progress engage the attention of the geological student. Sir Charles Lyell has given, in his admirable work, "The Principles of Geology," a very probable account of these stupendous changes, which it would exceed our limits to state or observe further upon; especially as it is our object rather to give facts than theories, however reasonable and interesting.

THE OOLITIC SYSTEM.

This geological division comprehends an extensive series of strata, consisting of imperfect shelly limestones alternating with deep beds of clay and calcareo-siliceous sand and sandstone, and extend-

ing north-west from the Island of Portland, on the coast of Dorset, to Whitby in Yorkshire. Rising from beneath the greensand on the east, and resting upon the lias formation on the west, throughout its whole course, its boundary lines are exceedingly devious and irregular, being broken by deep valleys of denudation, and presenting many detached or outlying masses, particularly towards the southern extremity of its range in the counties of Gloucester, Somerset, and Dorset. Its breadth is equally irregular, varying from a few miles near the two extremities, to fifty and sixty in its midland course.

The oolite strata are divided by geologists into four groups, distinguished by the terms upper, middle, and lower oolite, and the lias. The hard rocks of each of these form at their successive terminations abrupt ridges or escarpments, while the intervening clays or sands subside into plains, or a more or less level surface of variable extent. The oolites occupy considerable but very variable portions of the following counties:—Yorkshire, Lincoln, Leicester, Rutland, Northampton, Huntingdon, Bedford, Buckingham, Oxford, Warwick, Worcester, Berkshire, Wilts, Gloucester, Somerset and Dorset. The oolites of Scotland are extremely limited, being confined to a very small part of the east coast of Caithness, and some scattered and insignificant patches of lias on its western shores and islands. None of these strata occur in Ireland. On the continent, they prevail extensively in France, Switzerland, and Germany. They surround the basin of Paris, and form the great mass of the Jura mountains, from which circumstance *the series* has derived the name of the Jura forma-

tion, and jurassic rocks, terms which geologists often employ in speaking of them.

THE UPPER OOLITE, OR PORTLAND STONE, AND
KIMMERIDGE CLAY.

This formation is of less extent than the other divisions of the oolite system, occupying detached portions on their eastern border throughout the greater portion of their range. It consists of several beds of imperfect limestone resting upon one of clay. The principal quarries of Portland stone are at Portland, Purbeck, in Dorsetshire, and Font-hill and Tisbury, in Wiltshire; and the former place supplies the valuable building-stone generally used in London for ornamental architecture.

The following account of the Portland quarries is given by Mr. Webster:—

“The uppermost beds of the Isle of Portland, and they are numerous, consist of an oolitic rock. That which appears on the summit, and is called the cap, is of a yellowish colour and porcellaneous character, and is only burnt for lime. The next bed is worked for sale, being the best building-stone. Those below this bed contain numerous casts of shells that injure the stone, which is therefore only used for coarser purposes, and with these beds alternate others consisting of chert (flint).”

These beds abound with organic remains, consisting chiefly of shells, and amongst them very large ammonites, two or three feet in diameter, and large fragments of wood. But the most remarkable circumstance connected with organic life is the occurrence of fossil stumps of trees, with their roots in the ground, called a dirt bed, which is *thus described by Sir Charles Lyell*:—

“At the point of contact of the inferior division of the Wealden or Purbeck beds with the more ancient marine system, a very curious phenomenon is observed; the fresh-water calcareous strata repose, both in Purbeck and Portland, upon the oolitic limestone called the Portland stone, which abounds with ammonites, trigoniæ, and other marine shells. Between the two formations there intervenes a layer of what appears to have been an ancient vegetable soil; it is of a dark brown colour, contains a large portion of earthy lignite, and like the modern soil on the surface of the island, many waterworn stones.

“This layer is called the dirt-bed by the quarrymen, and in and upon it are a great number of silicified trunks of coniferous trees and other plants. Many of the stems of the trees and other plants are still erect, as if petrified while growing and undisturbed in their native forest, the former having their roots in the soil and their trunks extending into the superincumbent strata of limestone. The same circumstance occurs on the cliffs of the Bolonnais, on the coast of France. We must conclude that the stratum formed dry land at a remote period, upon which the trees grew; that it was subsequently submerged with the trees upon it, so as to admit of the incumbent strata being formed upon it, and ultimately raised to its present position. Perhaps in the whole range of British geology there is not so striking a proof of the successive existence of land and water upon the same spot, and of those changes which the face of the globe must have undergone at remote periods during the deposition of the strata, which finally emerged from the water and at present form the dry land.”

THE KIMMERIDGE CLAY.

This stratum of clay, which underlies the Portland stone above described, derives its appellation from a bay or village of that name in the Isle of Purbeck. It consists of blue and yellowish slaty clay, containing calcareous matter, (which is indicated by its effervescing with acids,) and both vegetable and animal remains. Some beds of the clay are so bituminous as to be used for fuel, and are called Kimmeridge coal. This imperfect coal burns heavily with a yellow smoky flame and bituminous smell. Some of the beds contain sulphate of lime and iron pyrites. The deceptive appearance given by these combustible shales has led in this case, as in many others, to several unsuccessful sinkings for more perfect coal, as at Sunning Well and Oxford, and near Farringdon in Berkshire. The presence of sulphate of lime is easily accounted for. The iron pyrites undergoes decomposition and produces sulphuric acid, which uniting with the calcareous matter forms the sulphate in question. This stratum contains numerous organic remains, and amongst others those of the lizard-shaped or Saurian animals and shell-fish, including nautilites, ammonites and belemnites, with many others.

The observed thickness of this bed of clay varies exceedingly; from 70 to 700 feet. The surface forms cold wet soils, better adapted to pasture and the growth of timber than arable culture; but it is one of those soils calculated to exercise the skill of the enlightened farmer in draining, and burning the clay, by which so much remains yet to be effected in the improvement of land; and the cal-

careous matter in the clay is a circumstance highly favourable to the benefit that might be derived from the latter practice. The soil improves in the neighbourhood of the junction of the stone with the clay, from the increased proportion of calcareous admixture, and the consequent greater openness of its texture.

Water is not abundant in this formation, and is said to be of bad quality, probably owing to the prevalence of iron pyrites and sulphate of lime, which are calculated to produce hardness and an ill flavour.

CHAPTER VII.

THE MIDDLE AND LOWER OOLITIC SYSTEM.

Middle Oolite, including the Coral Rag and Calcareous Grit—Building-stone of Oxford—Fossil Remains of the Calcareous Grit—Thickness and elevation.—Oxford Clay—Mineral character—Fossil Shells—Inflammable Shale—Melksham Spa—Extent and thickness—Agricultural character—Water and Mineral Springs—Bagly Wood—Diluvial Pebbles and Blocks.—Lower Oolite, extent and several members of.—Cornbrash.—Forest Marble.—Great Oolite Building-stone of Bath and Westminster Abbey—Fuller's Earth—Stonesfield Slate—Inferior Oolite—Extent and mineral character—Building-stone of Wells Cathedral and Glastonbury Abbey—Scenery and agricultural character—Description of west of Bath.—Valleys of denudation—Remarkable subsidences.—Fossil Remains—Thickness and elevation—Springs.—Appearance of the Strata.

CORAL RAG AND CALCAREOUS GRIT.

THESE strata repose upon that deep argillaceous bed, called the Oxford clay, and consist of several beds of more or less gritty imperfect limestone. The upper portion affords the perishable imperfect limestone formerly used in the public buildings at Oxford, which have suffered so much from the dilapidation of so perishable a material, which is very inferior in durability and appearance to the oolites both above and beneath it, as the Portland and Bath stones. It is full of broken shells, and contains from a tenth to a third of sand.

The coral rag, which lies beneath this freestone, is a loose rubbly limestone, consisting chiefly of branching madrepores, the beds of which are used for burning lime and mending the roads. These

beds repose upon the calcareous grit, which is composed chiefly of siliceous sand of a yellow colour, with about one-third of calcareous matter.

Fossil shells abound in these strata, and the remains of saurian animals have also been discovered in them, and fossil wood often occurs in the calcareous grit. The thickness of the coral rag and calcareous grit taken together has been estimated at from 100 to 150 feet, and their greatest elevation above the sea, as at Whiteham-hill, in Berkshire, 576 feet.

OXFORD CLAY.

This stratum, which underlies the before-mentioned coral rag and calcareous grit, is of great thickness, and consists of a dark blue tenacious clay, brown upon the surface, containing geodes, or masses of septaria or cement stone, locally called turtle-stone and Melbury marble, from some of the specimens being capable of receiving a polish, as at Melbury in Dorsetshire. This clay is sometimes mixed with calcareous and bituminous matter, producing in the latter case an inflammable shale, which, like those of the Kimmeridge clay before mentioned, has, in the days of ignorance of geology, led to abortive attempts to find useful coal. Singular beds of limestone occur in the lower part of this stratum, consisting almost entirely of a mass of fossil shells, which being found at Kelloway Bridge, near Chippenham, has received the name of Kelloway rock. It contains also iron pyrites and sulphate of lime; and as some of the beds when burnt emit a very offensive smell, there can be no doubt of

the presence of free sulphur. The water of the Melksham Spa, the well of which is sunk in this stratum, is a sulphureous chalybeate. This clay accompanies the general range of the oolites from the coast of Yorkshire in the south and south-west direction, and with a very variable breadth, to the south of Dorsetshire. At the extremities it is very narrow, but in some localities, as in the south of Lincolnshire, it occupies a space of about fifteen miles wide, and as it proceeds southward forms part of the counties of Huntingdon, Bedford, Buckingham, Oxford, Wilts, Somerset, and Dorset. Through the eastern counties, the surface of this stratum is flat, and forms the clay of the fens, and nowhere through its whole course attains any considerable elevation. At Boston in Lincolnshire this clay was sunk through to the depth of 478 feet, and its greatest depth is estimated at 700 feet.

The surface almost everywhere presents a cold ungenial soil, of difficult cultivation, and affording pastures of very inferior quality, abounding in carnation grass and other coarse herbage. The skilful application of capital in draining the surface and burning the clay, appears to be the most available and efficient means of correcting the natural defects of this and other similar soils, the improvement of which is probably destined to prove, at no distant time, one of the greatest triumphs of agriculture.

Springs are not abundant, and deep sinkings are necessary to obtain water, which, however, are not always attended with success.

Several mineral springs occur in this stratum, all of purgative qualities. The principal of these

are Stanfield, in Lincolnshire; Kingscliff, Northamptonshire; Cumnor, Berkshire; Holt and Melksham, Wiltshire.

The following interesting circumstance, with reference to the heights of Bagley Wood and Whiteham Hills, near Oxford, which chiefly consist of the strata of this formation, is mentioned by the Rev. W. D. Conybeare, and exhibits one of the many remarkable instances of the degradation many of the strata have undergone since their consolidation. "A large accumulation of diluvial pebbles and blocks, often of considerable size, and derived apparently from some transition district on one hand, and from chalk on the other, (comprising quartz, sandstone, like that of the Lickey, hard black flinty porphyry, and in addition to these, chalk-flints,) covers a great part of Bagley Wood, and pebbles of the same kind are scattered, though more sparingly, over the summit of Whiteham Hill. Now, since Bagley Wood is considerably elevated above the neighbouring district, and Whiteham Hill is completely insulated, steep, and at least 300 feet above the valleys which surround it, we have here a most decisive proof of the excavation of the valleys at a period long subsequent to the formation of those hills; since when these blocks and pebbles were transported hither, there must have been uniformly inclined plains from their native sites to their present locality. That they should have rolled up the present escarpments is physically impossible. The phenomenon is of exactly the same kind as that of the granitic blocks of the Alps transported to the sides of the Jura chain, but the inferences are here more direct, inasmuch as it is impossible to

call in the imaginary aid of icebergs to float the transported materials in this instance."

THE LOWER OOLITE.

This division of the oolites forms a nearly continuous chain of hills, extending from near Whitby, in Yorkshire, through the midland part of England, to Bridport on the British Channel, and consists of a series of strata of oolitic limestones, sandstones, sands, and clays; the oolites prevailing most in the south, and the sands and sandstones in the north. In the middle and southern part of the kingdom, where the system is more extensively developed, the strata have been distinguished by the following names:—Cornbrash, forest marble, great oolite, Stonesfield slate, fullers'-earth, and inferior oolite, with intervening beds of sand and clay, as the Hinton sand between the cornbrash and forest marble, and the Bradford clay above the great oolite.

In the northern or Yorkshire portion of this division of the oolites, the cornbrash is succeeded by sandstones and clays, shales with thin layers of coal, calcareous sand, and shelly limestone; and these, again, with sandstone containing clays and beds of coal and ironstone with vegetable remains; and, lastly, with limestone and sand, corresponding with the inferior oolite of the south. Similar beds to those of Yorkshire occur at Brora, on the east coast of the north of Scotland, viz. shelly limestones with alternations of sandstones, shales, and ironstone with plants; ferruginous limestone with fossil wood and shells; sandstone and shale with thin beds of coal.

The *Cornbrash* is a rough, imperfect, rubbly

limestone, of a brown and earthy appearance, having on the surface a reddish soil containing small roundish stones, which from their hardness are much used for mending roads at Chippenham and other parts of Wiltshire. Its beds generally separate into thin layers, and the stone is usually burnt for lime, but occasionally they afford masses of considerable thickness and solidity adapted to building purposes, as in the neighbourhood of Malmesbury in Wiltshire. This rock rests upon a bed of blue clay, sometimes of considerable thickness.

Forest marble is separated from the above by beds of siliceous gritstone, partially calcareous, with sand of the same character, and the stratum consists of thin beds of brownish shelly limestone, of which the more solid beds are sufficiently compact to receive a polish. The thin beds afford coarse roofing tiles and flagstones, much used for that purpose in the western part of Wiltshire and the neighbouring border of Somerset. The layers of this stone are generally separated by thin seams of clay, varying from an inch to a foot in depth, and the whole rests upon a deep bed of marly deposit called the Bradford clay, containing a great quantity of organic remains. This bed, though sometimes wanting, is usually of considerable thickness, varying from ten to forty or fifty feet.

The Great Oolite.—This member of the oolites is by far the most important of the series, and consists of calcareous beds of different degrees of firmness, having a total thickness of from 100 to 200 feet. The softer beds are characterised by those minute egg-shaped particles from which it has

derived its name, while the more compact beds have less of this appearance. The best of these beds afford the beautiful building material known as Bath stone, and is remarkable for the facility with which it may be wrought, either by the toothed saw or the chisel, as it admits of being sawn into blocks or slabs of any required thickness or dimensions, and of receiving every variety of architectural embellishment, and on that account was used for the repair of Henry the Seventh's Chapel at Westminster, so remarkable for its elaborate ornament. Blocks are raised from the quarries of this stone of very large dimensions, and it was principally used in the building of St. Paul's, for which it was obtained from Burford, in Oxfordshire. When taken from the quarry the stone is soft and of a yellowish colour, but becomes hard and whiter by exposure. The city of Bath is entirely built of this material; and many of the beautiful buildings for which it is celebrated, attest its excellence and durability. The hills round the city afford the greatest facility of obtaining the stone, as it generally forms the upper stratum, and they are extensively excavated for the purpose. In the softer stone the shells are so much comminuted that but few are discernible; but the hard coarse stone of the surface, and the compact and bluish beds beneath the best stone, are generally very shelly—in fact, consist almost entirely of a mass of shells. The quarries of Painswick, in Gloucestershire, yield a stone of remarkable beauty and fineness of grain, much used for the steps of superior houses.

Stonesfield Slate.—This stratum, though of very limited extent, is remarkable for the abundance,

peculiarity, and variety of its organic remains, both vegetable and animal. It occurs at Hinton, near Bath; Stonesfield, in Oxfordshire; Collyweston, Northamptonshire; and the Cleveland Hills, Yorkshire. The quarries at Stonesfield are celebrated for its fossils, and are thus described by the Rev. Mr. Conybeare:—"The assemblage of beds here worked consists of the fissile beds of a buff-coloured grey oolitic limestone, called *pendle*, each about two feet thick, separated by a bed of loose calcareo-siliceous sand, called *race*, about the same thickness. Concretions are frequent in the latter, and are called *whim-stones*, or *potlids*; they are partially oolitic, sometimes blue in the centre, and vary from six inches to two feet in diameter; their form generally is that of a flattened sphere; these break into parallel planes, and often contain shells. The *pendle*, after being quarried, is suffered to lie exposed to the action of a winter's frosts, and the blocks being then struck on the edge with a mallet, freely separate into plates sufficiently thin to afford materials for roofing. The quarries are principally situated in the valley immediately south of the village of Stonesfield, which branches off eastward from that of the Evenlode. The workings for this stone have been carried on from remote times to a considerable extent, so that both sides of the valley are completely honeycombed by them. Beautiful stalactites are often found in the fissures of the rock."

The fossil remains are those of tortoises, two or three varieties of the crab and lobster tribes, the palates and vertebræ of fishes, marine shells, birds, and different kinds of insects; but the most re-

markable organic remains are those of two animals of the insectivorous tribe, which have excited the greatest curiosity, as they are the only mammalian remains yet discovered beneath the tertiary strata in any part of the world.

The Fullers' Earth.—The Stonesfield slate, or the lowest beds of the great oolite, rest upon a deep bed of clay, partaking of the nature of fullers' earth, and in some localities affording good specimens of that material. In the neighbourhood of Bath, where the deep valleys cut through the great and inferior oolites, this bed of clay may be traced along the face of the upper portion of the hills, underlying the great oolite, and forming a band of wet, cold, and sterile soil, and affording good fullers' earth at Odd Down, overlooking the beautiful valley of Combehay. This clay also contains partial beds of rubbly stone of a blue colour, and sufficiently hard for making roads. This stratum of fullers' earth clay accompanies the great oolite in other localities, but is perhaps nowhere so well exhibited as in that above mentioned.

The Inferior Oolite is the lowest of the oolitic series; it consists of a coarse, gritty, calcareous rock, resting upon a deep stratum of calcareo-siliceous sand, co-extensive with the great body of lower oolites, and reaching from the mouth of the Tees to Bridport, Dorsetshire; sometimes, as in its midland course, spreading wide, and forming extensive tracts; and at others, seen only in steep escarpments, surmounted by the great oolite. Through the greater part of its course it is extensively denuded by transverse valleys, which cut down to the blue lias beneath, and cause its

boundary line to the west to be exceedingly irregular, presenting deep bays and numerous outliers.

The stone of the inferior oolite is distinguished from that of the great oolite by being much coloured with red oxide of iron, and also by containing more siliceous sand. Through the northern and midland course of this formation it consists of a siliceous and very ferruginous sandstone, with very little calcareous matter, sometimes affording hard gritty flagstones, and seldom producing good building-stone, while in the south-west it is more compact and calcareous, and supplies many quarries of valuable material, which, though of a darker colour, is scarcely inferior in other properties to the Bath stone. At Dundry Hill, near Bristol, an outlier of this rock is extensively quarried; and at Doultong, near Shepton Mallet, are the ancient quarries which supplied the stone of which Wells Cathedral and Glastonbury Abbey were built, many of the more delicate ornaments of which are still in a very perfect state. These quarries, and those of Ham Hill, near Yeovil, still continue to supply building stone for the western part of Somerset. The underlying sandy stratum is chiefly siliceous, with varying proportions of calcareous matter, and in many places contains beds of excellent marl, and concretionary and flattish masses of the same nature as the sand, with a greater quantity of oxide of iron. The sand is conspicuously exhibited in the face of the almost precipitous heights of Beachen Cliff and Beacon Hill, which overhang Bath on the north and south, and in other steep escarpments

of that deep oolitic valley, where the marly beds of this sand throw out the springs of excellent water with which the city is supplied.

In the midland counties, particularly in the western part of Oxfordshire and the adjoining portion of Gloucestershire, this sand is widely developed, and forms extensive tracts of reddish sandy soil of great fertility and of admirable consistence for all the purposes of agriculture. Through the western part of Gloucestershire the inferior oolite forms part of the bold escarpment of the Cotswold Hills, where it is capped by the great oolite; and further to the south of that locality, and in the north of Somerset, but little more than its edges are revealed on the sides of the deep valleys which descend through the oolites in that district, where the wild graces of sylvan scenery, blended with corn-fields, upland pastures, and rich bottom meadows, and enlivened by neat habitations and manufacturing industry, never fail to excite the admiration of travellers, as those will well remember who have descended Froster Hill and the valley of Rodborough. In the southern part of Somerset this formation again occupies a considerable breadth of surface, and from Ilminster to Sherborne, in the county of Dorset, its calcareo-siliceous beds afford a soil which has few rivals in England for the excellence of its pasture, its fertility under the plough, and the luxuriant growth and productiveness of its numerous orchards. In this district deep beds of very rich marl frequently occur, which, when spread upon the poorer and sandy pasture land, produces an astonishing improvement in the quality and quantity of the herbage. This marl

is generally obtained with the greatest facility, from the beds being exposed on the sides of the valleys by which this stratum is so deeply indented. In its lower portions this calcareous sand mingles with, and probably is in some measure improved by, the upper marly beds of the Blue Lias.

The Rev. W. D. Conybeare, to whom we are indebted for a very elaborate account of the British strata, gives the following very interesting description of the inferior oolite to the south and west of Bath:—

“ The inferior oolite generally forms lower terraces advanced in front of the higher table land, capped by the great oolite, and to the west of the general line of escarpment often constitutes detached summits or outliers, (as may be particularly observed south of the line between Bath and Bristol:) such are the ridge in which Newton Park stands, the conspicuous hummock of Stantonbury hill, crowned with an extensive and perfect British camp connected with, and strengthening the Belgic boundary line of Wansdike, the conical summits of the barrow hills, and the adjacent ridge called the sleight of Finsbury parish; but Dundry Hill, three miles south of Bristol, is the largest and most conspicuous of these outlying hills. This presents a long narrow ridge, nearly four miles from east to west, and sending off a short branch from its western extremity towards the south-west. The ridge rises about 300 feet above the level of the platform that supports it, and 700 feet above the level of the sea. It has a thick cap of the inferior oolite throughout, which has been very extensively quarried as a free-

stone near the western end ; the eastern exhibits a large camp, corresponding with that on Stantonbury, and forming a part of the same defensive line.

“ The principal escarpment of the inferior oolite, ranging on the east of these outlying summits, proceeds from Bath to the south-south-east above English Coombe, Preston and Paulton, being intersected, however, by several deep valleys of denudation which cut through the subjacent beds into the new red sandstone on which it rests. Clandown, above Paulton, is remarkable for the deep pits sunk through most of the intermediate beds into the regular coal measures ; one of these exceeds 200 fathoms in depth, but this begins in the lias ; another, just on the edge of the hill towards Paulton, commences on the inferior oolite. This pit is particularly interesting, as verifying the order of the intermediate beds, and exhibiting a singular instance, as far as this island is concerned, of any successful experiment to reach coal from beds so far above it in the regular series. No inference, however, can be drawn from this instance in favour of similar trials elsewhere, since two peculiar circumstances here occur : 1st, the manner in which these more recent beds overlie the coal-field, resting unconformably in horizontal plains on the truncated ends of the highly inclined strata belonging to the coal measures ; and, 2dly, the thinning out of many of the beds in this direction ; in consequence of which, the sands of the inferior oolite and the clay of the lias are greatly reduced, and have almost vanished in many places, leaving the freestone beds of the inferior oolite almost in contact with the lower stony beds of the lias ; the

new red sandstone also being greatly diminished in thickness, so that a geological interval, equal in many other districts probably to 2,000 feet, is here reduced to less than a quarter of that depth. South of Paulton, in Kilmarsden and Babbington parishes, the inferior oolite spreads over the same platforms with the diminished lias, and it becomes somewhat difficult, in many places, to trace the latter as a distinct formation. In the south of the latter parish, and in Mells, the horizontal plains of the inferior oolite come in contact with the inclined coal measures and mountain limestone constituting the eastern portion of the Mendip Hills, which expire in this direction by the lowering of their strata; so that they become buried beneath the level of the more recent formations, and are here exhibited only in the bottom and sides of the valleys of denudation. Such is the character of the district lying between Wells on the north, Frome on the west, and the two Cranmoors on the south. An uniform and elevated plain of the inferior oolite spreads over its whole surface, furrowed by valleys about 150 to 200 feet deep, which expose the mountain limestone. The character of many of these valleys, particularly of that between Wells and Frome and its lateral branches, is highly romantic; the streamlets which flow through them being skirted by bold and rocky banks overgrown by the feathering woods; while the geologist observes, as a feature of peculiar interest in their precipitous escarpment, the actual contact of the horizontal bed of the inferior oolite resting on the truncated edges of the mountain limestone, thrown up in an angle of fifty to sixty degrees. This

line of contact is sometimes perfectly level for a considerable distance, as if the edges of the mountain limestone strata had been rendered smooth by some mechanical force abrading them previously to the deposition of the inferior oolite, but in other instances it is rugged and irregular; sometimes the contact is marked by a breccia of fragments of the older cemented by the newer rocks, but this is by no means constant. On the north of Doultong Hill, between West Cranmore and Shepton Mallet, the inferior oolite abuts against the old red sandstone, which forms the nucleus of the Mendips, and here begins to display itself in considerable eminences at Downhead Common. Between Doultong and Shepton Mallet, the inferior oolite and lias abut against the inclined strata of the Mendip under such circumstances, and with such considerable variations from their usual aspect, that it is not easy to pronounce to what formation many of these anomalous beds belong. Similar beds continue to hang on the southern slopes of the Mendip, on the north of the line between Shepton Mallet and Wells. It is only however when immediately in contact with the Mendip range that this obscurity prevails; for, from Doultong, the general line of the inferior oolite is continued south by Cannard's Grave towards Bruton, forming a conspicuous escarpment rising above the lias plains which extend westward; over these some outlying hills of the same formation are scattered, viz. the long range of the Pennard Hills, and the more striking and far-seen cone of Glastonbury Tor. Brent Knoll, a lofty lias hill, rising out of the marshes on the border of the Bristol Channel to the height

of between 400 and 500 feet, also exhibits on its summit a cap of inferior oolite, nearly co-extensive with the ancient escarpment which surrounds it.

“ But to return to the main escarpment ; this ranges from Bruton south-west to Castle Cary, and thence south by the two Cadburys, near the most southerly of which a detached summit of this formation gives position to the boldest and strongest ancient encampment extant in the island, girding its sides with triple fosses and stupendous mounds. Near this point the range circles westward, round the vale of Marston Magna, pursuing a line between Ivelchester and Yeovil, to Ilminster. Between Ilminster and the coast the junction of the inferior oolite and sands with the lias ranges due south, but is very generally concealed by overlying hills of the greensand formation, supporting occasionally chalky summits, and connected with the great western extension of the beds towards the Blackdown Hills. On the coast, the series of beds of which we are now treating is finely displayed in the sections of the cliffs between Charmouth and the head of the Chesil Bank. Proceeding from west to east, we first find the inferior oolite resting on the lias marl on the summit of a steep pyramidal cliff, about halfway between Charmouth and Bridport Harbour, called the Golden Cup, (perhaps a corruption of the Golden Cap, as derived from the yellow-reddish colour of the summit, strongly contrasted with the dark blue of its base.) Down Cliff succeeds, in which the dip of the strata towards the east has brought them somewhat lower ; a third cliff, in which the inferior oolite and sands occupy the middle region, (the hill above being

crowned by the fissile variety of the great oolite,) intervenes before we arrive at the mouth of Bridport Harbour. The first cliff west of Bridport Harbour no longer exhibits the lias clays, these having been carried by their dip below the sea level, and the lowest visible beds being those which contain the concretions of green marly sandstone intermediate between the sands and the lias. In Burton Cliff, which follows this, the inferior oolite itself sinks in like manner, being succeeded on the east by a low cliff of the fullers'-earth clay, full of the fibrous calcareous spar."

The above details are interesting, as they bring before us some of the most striking phenomena connected with oolite series in a part of the kingdom where the country presents, in bold hills and numerous deep-sunk wooded valleys, an endless variety of picturesque beauty and grandeur to beguile the labours or gratify the taste of the geological explorer. That the inferior oolite has been extensively destroyed is evident from its numerous outliers, and deep valleys of denudation, as well as its exceedingly sinuous course and deep indentations, where it terminates upon the lias to the west. The deep valleys which cut through the oolites exhibit along their acclivities many remarkable subsidences, both of the inferior and great oolite. Several instances of these subsidences may be observed along the sides of the hills which overhang the left bank of the Avon, near Bath, by proceeding from the old road leading to Claverton Down, above Widcomb Crescent, along the face of the slope, or along the banks of the canal through the beautiful valley of Claverton. In several places the inferior oolite will be

seen to have slipped down so low as to form the bed of the canal, which is here cut through the rubbly and treacherous mass. On ascending the hill to the commanding eminence of Hampton Rocks above the woods, the great oolite, which caps the summit, will be seen to have slipped down in large detached masses, and to project in wild confusion over the steep woods beneath. Similar phenomena occur in the valley of Coombe and Mitford, and many other places. Few localities afford so much geological interest as the valley of the Avon and its branches, through the oolite formations in this neighbourhood, or a greater variety of picturesque scenery, which is often of surpassing beauty. Of the above-mentioned subsidences, some of the minor ones might have been occasioned by the springs carrying away the marly beds upon which the rock rested ; but by far the greater part must have been produced by a more powerful and general cause, and must be attributed to the destructive and denuding force of the water by which these valleys were originally excavated, and which, by undermining the rocky masses, caused them to sink down often to great depths below their original position.

The inferior oolite abounds in fossil remains, chiefly consisting of shells, and in common with all the other oolites which have been described, as well as the older limestone, yet to be noticed, appears to have derived the greater part of its substance from the accumulations effected by means of organic life, in the same way that rocks are now forming in our tropical seas by the ceaseless action of zoophytic or coralline animalculæ, secreting carbonate of lime from the water. These accu-

mulations were more or less blended with the sandy and earthy deposits, and with the shells, broken or entire, of the many species of shell-fish which inhabited the same seas, frequently mingled with the remains of saurian, or lizard-shaped animals, and other reptiles, which during the whole period of the formation of the later secondary rocks were so abundant as to have obtained for it the title of the Saurian period.

The following hills are perhaps the highest of this formation. Rosebury Topping, in Yorkshire, 1,022 feet; Arbury Hill, Northamptonshire, 804 feet; Epwell Hill, Oxfordshire, 836 feet; and Dundry Hill, near Bristol, 700 feet, respectively above the level of the sea. The thickness of the inferior oolite, with its sands, is estimated on the average to be about 400 feet.

Springs of water are abundant in this as well as the other oolites, as may be expected from the frequent alternations of porous and retentive deposits by which they are characterised; and all the valleys of these formations afford, in proportion to their depth, copious streams of excellent water. Speaking generally of the soils afforded by the oolites, they are inferior to many others for arable culture, though the pastures and the meadows are often of superior quality, especially those of the formation now under consideration, and which we have previously noticed.

The evidences of the changes which the surface of the earth has undergone, are in some measure hidden from our sight by the vegetation with which it is covered; but if to the mind's eye we divest it of its verdant mantle, the destruction which the strata have suffered will then be ex-

hibited in all the imposing grandeur of its real character, as manifested in the upheaved fragments and detached portions, and the deep, and often wide valleys, which divide rocks, evidently once continuous over the intervening space. The actual state of the strata thus broken and dismembered, has been compared to the ruins of an artificial structure of colossal dimensions; the broken walls and separated fragments of which indicate the extent, if not the perfect form of the original building, and the destructive violence and subsequent spoliation to which it has been subjected. Such a comparison would, perhaps, nowhere better apply than to the actual state of the great and inferior oolites, with their deep valleys of denudation, their bold and abruptly-broken eminences and out lying masses.

CHAPTER VIII.

THE LIAS FORMATION AND NEW RED SANDSTONE—MAGNESIAN LIMESTONE.

General character of the Lias Formation—Section of, obtained by sinking near Bath—Range and extent—Thickness and elevation—Remarkable Organic Remains—Alum Shales of Whitby, and mode of making Alum—Agricultural character—Mineral Springs of Cheltenham, Bath, &c.—Water.—New Red Sandstone, or Red Marl—Range and extent—General character—Building-stone—Artificial Caverns—Brine Springs and Rock Salt—Section of the Strata at Northwich—Beds of Gypsum—Thickness and elevation—Agricultural character—Water and Medicinal Springs—Fossil Remains.—Magnesian or Conglomerate Limestone—Character as a Building-stone—Analysis of—General Properties—Section of in the North of England.

THIS is the lowest of the series of limestones and clays included under the general term of the Jura formations, in which it is classed with the oolites, though possessing but little of the peculiar character of those rocks. It consists of numerous beds of marly clay, separated by layers of imperfect limestone, varying from a few inches to several feet in thickness. The thinness of many of these beds of stone, and the regularity with which they are superimposed upon each other, when a vertical section is exposed in a quarry, or when they form cliffs on a sea-shore, produce a ribband-like appearance. The stone of the upper beds is soft, and contains much clay, but those in the lower part of the formation are more compact and calcareous, and consist of blue and white stone, divided by very thin seams of clay or marl. Several of the beds afford valuable slabs for

paving and the floors of houses, and being capable of receiving a tolerable polish, are frequently used for ornamental purposes. The remarkable stone called Cotham marble, or landscape stone, is found in detached masses of this formation. In the districts where the Lias occurs, it is extensively used both in agriculture and building; for the latter purpose it is rather a perishable material if much exposed to the weather, and requires to be selected with care for that purpose, and laid in walls in its natural position. It produces a good lime, which has the valuable property of setting under water, and is thence called hydrauliclime; but this property pertains more particularly to nodules of this stone found in the irregular beds, and which, like those of the London clay, are called cement stones, and septaria. The clays of this formation are in some situations more or less bituminous, and the kilns where the stone is burnt emit a disagreeable and offensive smell, perhaps partly owing to iron pyrites, which is very common in this formation, the decomposition of which produces the alum shales of Whitby, on the coast of Yorkshire, and the spontaneous inflammation observed on the coast of Dorset. The abundance of bitumen in some parts, has led in this, as in many other instances, to fruitless sinkings for coal. A remarkable instance of these unsuccessful trials for coal at Bath Easton, near Bath, is recorded by the Rev. W. D. Conybeare, of which an accurate account was preserved. On this occasion the lias formation was sunk through, and, as it contains, perhaps, a more particular description of the several beds than any other, it is given below :—

		Ft.	In.
	Yellow clay . . .	8	0
	Blue marl . . .	27	0
	Stone . . .	0	6
	Blue marl . . .	18	0
	Stone . . .	0	4
	Blue marl . . .	9	0
	Blue rock . . .	12	0
	Marl . . .	1	0
	Stone . . .	1	6
	Blue marl . . .	24	0
	Rock . . .	3	0
	Marl . . .	6	0
	Stone . . .	0	10
<i>Upper Marl . .</i>	Blue marl . . .	41	0
	Stone . . .	0	10
	Blue marl . . .	7	0
	Stone . . .	0	9
	Blue marl . . .	7	0
	Stone . . .	0	9
	Blue marl . . .	6	0
	Stone . . .	0	4
	Marl . . .	3	0
	Marl and stone . .	11	6
	Stone . . .	0	9
	Marl . . .	2	6
	Stone . . .	3	0
	Marl and stone . .	8	0
	Ditto . . .	12	3
<i>True Lias Beds .</i>	Hard marl . . .	4	0
	Hard rock . . .	18	0
	Blue stone . . .	5	1
	Hard blue stone . .	12	1
	Stone . . .	2	0
<i>Lower Marls . .</i>	White Lias rock . .	10	0
	Blue marl . . .	6	0
	Stone . . .	0	6
	Clay . . .	0	9
	Rough blue marl . .	0	5
	Black marl . . .	10	0
	Light blue marl . .	2	0

Red Ground of New Sandstone Formation.

The Lias formation is one of the most extensive the secondary rocks of England, and stretches

from the mouth of the river Tees, on the north coast of Yorkshire, to Lyme Regis, in Dorsetshire; after crossing the Humber, it follows the course of the Trent to Newark, from whence, proceeding in a nearly south-west direction, it occupies a large portion of the counties of Rutland, Leicester, Northampton, Warwick, Oxford, Worcester, and Gloucester; about Bath its continuity is somewhat broken, but it again spreads wide in the lower part of Somerset, at the foot of the Blackdown, whence it continues, with but little interruption, to the coast at Lyme Regis. On the eastern side it is laid bare by the valleys of denudation, which cutting through the incumbent oolites, give it an exceedingly irregular outline; on the west the boundary line is less broken, but nevertheless exhibits numerous projections, with some outlying masses, and a large detached mass occurs as far west as Whitchurch, in Shropshire. Many detached portions or outliers occur in the north-east of Somerset, and a long ridge called the Hog's Back, extending into the marshes of that county, points to the remarkable outlier Brent Knoll, and that beyond the river Parret, on the coast of the Bristol Channel. In South Wales the lias occupies a considerable part of the sea-coast of Glamorgan, with outliers at Cardiff and Newport. A small portion of this formation occupies the southern part of the Isle of Skye, on the western coast of Scotland.

The surface of the lias strata is generally flat, with occasional ridges of no very considerable elevation; but on the west it occupies higher positions, where it is seen resting unconformably upon broken edges of the highly-inclined moun-

tain limestone, as remarkably displayed on the road leading from Shepton Mallet to Frome, just above the former town; it rises to a considerable height at the eastern end of the Blackdown, of which it forms the base for a considerable distance; but perhaps it attains its greatest elevation along the flanks of the Mendip Hills, where it is probably 500 feet above the level of the sea. Its thickness in the midland counties is estimated at from 400 to 500 feet.

The fossil remains of this formation are very numerous, and some of them of the most extraordinary character. The most remarkable of the inhabitants of the sea in which those rocks were deposited, was the *Ichthyosaurus*, which appears in some respects to have resembled the grampus, with four large paddles, and a long tail. Its jaws were of the most formidable kind, having an opening in some specimens of eight feet, of a tapering and pointed form, and armed with rows of conical teeth, in some instances 200 in number. It appears to have been an animal of the most ferocious character, preying not only on fish, but upon the smaller fry of its own species, as has been ascertained from the undigested bones preserved in the coprolite, or fossil dung, a fact which, after the lapse of such immense periods of time has lately been revealed to us by the researches of Professor Buckland. The eyes of this reptile were proportioned to the size of the body, being remarkably large, and in some instances of the size of an ordinary dish, and of a structure calculated to give it great powers of vision for the pursuit of its prey. The numbers of these animals inhabiting the ancient seas must have been enormous, as the

remains of their bones and fossil dung are found in such quantities in some of the lias beds as to have entitled them to the name of bone-beds. The extraordinary structure of this animal is thus described by Baron Cuvier:—"It has the snout of a dolphin, the teeth of a crocodile, the head and sternum of a lizard, the paddles of a whale, and the vertebræ of a fish." Another monster, the remains of which are found in the beds of the lias, is the *Plesiosaurus*, which, with a shorter body, was also furnished with four paddles, and a long neck, like that of a serpent, and a small head; a structure which fitted it to find its prey in shallow waters, or for seizing such as flew above them. Both these animals are altogether different from any now existing in our planet. The remains of these reptiles have been found nearly perfect in the lias beds of Whitby and Lyme Regis; and beautiful specimens of them, as well as of their disjointed members, are preserved in the British Museum. From the bone-beds of this rock at Westbury, near Bristol, and the fragments frequently met with by the quarrymen in the interior of Somerset, at Street, near Wells, and Pylle, near Shepton Mallet, as well as at the places on the coast above mentioned, it seems highly probable that they might be found in every portion of the lias formation, if sought for; and as the rocks in which they are discovered contain a large portion of phosphate of lime, such discoveries are calculated to confer a lasting and valuable benefit upon agriculture, by supplying that indispensable substance, phosphate of lime, or bone-earth, of which Dr. Turner found 50 per cent. in the fossil bones and teeth of these saurians, and some speci-

mens of the lias lime have afforded as much as 14 per cent. The remains of shell-fish are very numerous, including several species of ammonites, with nautilites, gryphites, and belemnites; the former are often very large, and of such frequent occurrence, as to occupy a considerable portion of the beds at Lyme Regis, which have been laid bare by the action of the sea, and present an extensive beach at low water. Wherever the rock is broken, others present themselves which have been enveloped in the stony mass. In the lias countries these are frequently seen in the face of walls built of this stone, and also in the fragments used for mending roads, sometimes composing almost the entire mass. These fossils often contain sulphuret of iron, and when they are sawed through, exhibit the chambers of the shell beautifully marked by that mineral, which seems to have taken the place of the walls which divide them.

The vegetable remains consist of gigantic reeds and fossil wood; the reeds sometimes standing erect as they grew, but generally broken off; at others they lie flat, and are compressed; both presenting sandstone casts. The wood in many instances is charred; in others silicified, or coated with agate, or penetrated with oxide of iron. In the alum shale of Whitby are found the trunks and branches of trees, the bark and softer parts of which have been converted into jet; and leaves and impressions like those of the palm are found in the sand and ironstone of the same place.

The alum strata and the process of making alum are thus described by the Rev. W. D. Conybeare:—"Over the alum shale lies a bed of hard

compact stone six or twelve feet thick; the workmen call it *dogger*, a name by which they also designate the septaria or cement stone, and the component parts appear to resemble each other. The colour of the recent fracture of the dogger is bluish-grey, divided into nearly cubical masses by transverse fissures, filled with a soft ferruginous earth, containing thin ochreous plates, having the earth between them. The whole of the upper part of the alum shale resembles indurated clay when first wrought, but by exposure to the atmosphere, it suffers decomposition, and crumbles into thin layers. The colour of the shale is bluish-grey, and varies in hardness. The upper part of the bed near Whitby may be crumbled in pieces between the fingers, but at a considerable depth is as hard as roofing slate. At the depth of about 250 feet from the top of Boulby Cliffs, which rise 450 feet above the level of the sea, the shale loses its unctuous feel, and becomes mixed with a large portion of sand and mica, in shining scales. It becomes of a light-grey colour, and encloses seams of ironstone; but below this part the rock resumes its softness and smoothness. It abounds in iron pyrites. The upper part is most abundant in sulphur, which decreases in going down; but the bituminous substance increases, and the rock becomes hard and slaty; so that a cubic yard taken at the top of the stratum is as valuable as five cubic yards taken at the depth of 100 feet. When a quantity of the schistus is laid in a heap, and moistened with water, it takes fire spontaneously, and will continue to burn until the whole of the combustible part is exhausted. A part of the cliff that fell some years ago was exposed

to the tide, when it took fire, and continued to burn during two or three years. That part of the alum shale of Whitby which is earthy, rather than slaty, yields the greatest quantity of alum. A layer of brushwood is laid in the first instance, and shale is thrown down upon it, until a considerable mound is raised. The brushwood is then lighted, and a slow combustion ensues; another layer of brushwood is then placed beside the first, and is, in like manner, covered by a mound of shale; still others are added; and these mounds, with fires beneath, are extended on all sides. When the shale has effectually caught fire, it continues to burn without any addition of fuel. It is afterwards thrown into vats of water, and boiled twenty-four hours; it is then conveyed into other vats, where, an alkali being added, it crystallizes; it is then dissolved again, and purified by a second crystallization. When thus prepared, it is shipped off for London, and thence to Sweden and Russia."

The cold clay soils of the lias formation are unfavourable for tillage, but afford, when drained and skilfully managed, good crops of wheat and pulse, especially tares, to which they are very favourable.

The pastures, especially the uplands, are cold and backward, and the herbage coarse and inferior, though capable of great improvement by draining and manuring; and some of the lowlands are well adapted to the dairy, and the orchards upon them produce excellent cider, particularly when the upper beds blend with the lower ones of the oolitic sand. This formation seems to present, perhaps more than any of the clays, the

means of agricultural improvement, by burning the shelly beds, which are rich in calcareous matter, and, in some places, in organic remains and phosphate of lime. It is more than probable that the lime produced from the beds of this stone owes its fertilizing properties chiefly to the latter substance, as it is found to have a most beneficial effect upon the wheat crop, which immediately succeeds its application.

The mineral waters of Leamington, Warwickshire; Cheltenham; Glastonbury; Alford, near Castle Cary; and the hot springs of Bath, rise in this stratum. The following are the analyses of the celebrated saline waters of Bath and Cheltenham:—

Bath Waters, by Scudamore.

SOLID CONTENTS OF A PINT.

	Grains.
Muriate of lime	1.2
Muriate of magnesia	1.6
Sulphate of lime	9.5
Sulphate of soda	.9
Silica	.2
Oxide of iron	.02
Loss, partly carbonate of soda	.58
	14.

Cheltenham Waters, by Parkes and Brande.

SOLID CONTENTS OF A PINT.

	Grains.
Sulphate of soda	15.
Sulphate of magnesia	11.
Sulphate of lime	4.5
Muriate of soda	50.
	80.5

Large supplies of water are generally obtained in the lias by sinking to the lowest beds.

THE NEW RED SANDSTONE, OR RED MARL.

This formation extends from a little to the south of Hartlepool, in the county of Durham, to Torbay, on the south coast of Devonshire, occupying a considerable portion of the counties of Durham, York, and Nottingham, and spreading wide over the midland counties, including Derby, Lancashire, Cheshire, Shropshire, Staffordshire, Leicestershire, Warwickshire, Worcestershire, Gloucestershire, with a portion of Somerset and Devon. The breadth is much contracted in Gloucestershire, and from thence is much broken and overlaid in its course towards the south coast. A detached portion occurs in Cumberland, surrounding the city of Carlisle.

Generally speaking, this formation may be said to consist of strata of siliceous sand, clay, (sometimes calcareous,) and beds and conglomerates of boulders and pebbles, derived from the destruction of older rocks.

The clay and sandstone are either red or of a salmon colour, sometimes exhibiting streaks of a light blue and cream colour, and at others becoming nearly white. Though the sandstone and clays are often interstratified, generally the conglomerates form the lower portion, the sandstone the next, and the clay or marl the uppermost. At Sidmouth, on the south coast of Devon, where the cliffs rise about 800 feet above the sea beach, the sand occupying the lower portion is covered by the red clay or marl of 300 or 400 feet in thickness, which is again surmounted by a deep bed of the greensand, containing flints. Deep beds of conglomerate occur in the valleys of

Somerset, to the west of the Quantock Hills, and also in Devonshire, on the road to Exeter, where they are quarried for the limestone boulders and for mending the roads.

Many places derive their names from the striking and prevailing red colour of this formation; as Rougemont Castle, Exeter; Radstock, Redhill, and Redcliffe, Somerset; Red Marley, Worcestershire; Radford, Warwickshire; Retford, Nottinghamshire; Rotherham, Yorkshire, &c.

The sandstone is generally rather fine-grained and of soft texture, and therefore too perishable for architectural purposes, though in some situations it affords a stone of excellent quality, and nearly white. In many localities this rock has been extensively excavated in ancient times, of which there is a remarkable instance at Nottingham, which is called the Home of Caverns. An obscure tradition prevails, that these and similar caverns were formed for the purpose of habitation; and some of them are called Druids' caves. The cliffs or sections of this sandstone have a remarkably uniform appearance wherever they occur; and these, as well as the soils they bear, have a rich, warm, and agreeable effect in the landscape.

The mineral contents of this formation are very remarkable and important, as it affords beds of rock-salt of great thickness, and inexhaustible brine-springs, as at Northwich and Namptwich in Cheshire, and Droitwich in Worcestershire; from which circumstance it is sometimes called a saliferous formation. In the valley of the Weaver, which river flows through the red marl in Cheshire, numerous springs occur, which contain above

twenty-five per cent. of salt. There are several solid beds of salt, with abundance of gypsum, also in this valley. The most important of these occur at Northwich, where two beds of rock-salt are worked, the united thickness of which appears to approach 200 feet. This deposit of salt extends over a space about a mile and a half in length, and three quarters of a mile wide, and therefore would appear to be inexhaustible. The following is a section of the workings, given by Dr. Holland.

Section of the Strata sunk through to the Second Bed of Rock-Salt, at Witham, near Northwich.

	Ft.	In.
1. Calcareous marl	15	0
2. Indurated marl	4	6
3. Indurated blue clay, with sand	7	0
4. Argillaceous marl	1	0
5. Indurated blue clay	1	0
6. Red clay, with sulphate of lime irregularly intersecting it	4	0
7. Indurated brown clay, with grains of sulphate of lime	4	0
8. Indurated brown clay, with sulphate of lime crystallized in irregular masses and in large proportion	12	0
9. Indurated blue clay laminated with sulphate of lime	4	6
10. Argillaceous marl	4	0
11. Indurated brown clay, with sulphate of lime	3	0
12. Indurated blue clay, with ditto	3	0
13. Red and blue clay	12	0
14. Indurated brown clay, with sand and sulphate of lime. The fresh-water (860 gallons per minute) finds its way through holes in this stratum, and has its level at 16 yards from the surface	13	0
15. Argillaceous marl	5	0
16. Indurated blue clay, with sand, and grains of sulphate of lime	3	9
17. Indurated brown clay, with a little sulphate of lime	15	0
18. Blue clay, with sulphate of lime	1	6

	Ft.	in.
19. Brown clay, with sulphate of lime	7	0
20. First bed of rock-salt	75	0
21. Layers of indurated clay, with veins of rock-salt running through them	31	6
	230	9
22. The second bed of rock-salt, which has been sunk into 105 to 108 feet.		

These mines of rock-salt are worked somewhat after the manner of coal mines, by leaving large pillars to support the roof, and afford upwards of 60,000 tons of salt annually, the larger portion of which is exported, and the remainder purified by dissolving it in water and subsequent crystallization. The Cheshire mines of rock-salt were discovered by an unsuccessful sinking for coal in the year 1670, previous to which the supplies of salt were obtained from the brine springs of Droitwich. From these two sources is derived almost all the salt consumed in England, and upwards of half a million tons for exportation.

The following are the beds sunk through in Worcestershire:—mould 3 feet, marl 35 feet, gypsum 40 feet; a river of brine 22 inches, gypsum 75 feet; a rock of salt bored into 5 feet but probably extending much deeper. In Nottinghamshire, masses of gypsum are seen imbedded in the marl on either side the railroad, where the deep cuttings pass through it. Coast Cliff on the Severn exhibits large layers of gypsum, and the cliffs at Watchet on the north coast of Somerset are intersected with it in all directions; gypsum occurs at Somerton in the same county, and seems indeed to be a prevailing mineral in the red marl. Lead and copper ores are also said to be found in this formation, but not in any workable quantity.

The thickness of the strata varies very much ; in the county of Durham they have been sunk into more than 700 feet without passing through them. At West Bromwich the Earl of Dartmouth has lately sunk through the new red sandstone many hundred feet into the rich coal beds beneath. At Sidmouth, in Devon, the lofty cliffs composed of sandstone and marl exhibit a face of at least 600 feet, and the sand rock is with good reason supposed to descend far beneath the level of the sea. In Somerset, however, this formation appears to thin out, and the coal pits near Bath are sunk through it, together with the overlying lias and inferior oolite, into the coal measures. At Puckle-ridge, in Gloucestershire, also, it has no considerable thickness, as it was passed through in sinking for coal at the depth of 153 feet ; while at Evesham, in Worcestershire, it was found to be 600 feet thick.

Though the new red sandstone spreads over so wide a portion of the central part of the kingdom, it nowhere attains to any great elevation, as the highest part which divides the tributary streams of the Trent and Severn does not exceed 400 feet above the level of the sea.

Great difference exists in the agricultural character of this formation, some portions being so sterile as scarcely to support any vegetation, from the extreme looseness of the sand and the very small quantity of impalpable matter in the soil. In the tract called the Forest of Sherwood, in Nottinghamshire, the soil consists for the most part of a deep, loose, and very fine sand, so light, as in dry weather to be driven in clouds before the wind ; yet by the application of skill and

capital, the effect of which is nowhere more conspicuously manifested, the drifting unpropitious soil is made to bear remunerating crops of turnips, barley, clover, grass, rye, and even wheat. Where the sands are heavier, the skill with which they are cultivated renders them exceedingly prolific in all the usual products of convertible husbandry; while the mixed soils and the marly districts afford the most fertile arable and pasture land of any of the regular strata of England; and it might be safely asserted that no other district presents more beautiful and numerous instances of the combined effect of high cultivation, affluence, and taste, which are the general characteristics of British scenery, and excite the admiration of foreign travellers. Besides the productiveness of the soils of this formation under cultivation, it sustains some of our finest forests of native timber, the oak of which is highly prized by the ship builder, both on account of its size and durability. The Forest of Sherwood, which once covered a large portion of the county of Nottingham, but which has now almost entirely given way to cultivation, is remarkable for the gigantic size of its oaks, of which many monumental specimens remain, though in a state of extreme decadence. One of them, on the estate of the Duke of Portland, at Welbeck Abbey, is of such dimensions as to admit of the passage of a carriage through the opening of its decayed trunk. The magnificent Parks of Clumber, Welbeck, Thorsby, and Worksop Manor, with their extensive woods and plantations, together with the rich grovy scenery of Osberton, Curlton, and other neighbouring beautiful localities, sustain in some degree the fallen grandeur of

the ancient and once noble Forest of Sherwood. The extensive destruction of this forest, however, cannot be regretted, since from being the unproductive harbour of lawless bandits, it is now adorned with princely mansions and the cheerful habitations of respectable yeomen, and a thriving population, whose skilful and productive labours reflect the highest honour upon British agriculture.

In the marl of this formation it is generally necessary to sink deep for water, and it is usually hard when obtained, from the prevalence of sulphate of lime (gypsum); but in the sand rock it is often obtained at a much less depth, and usually of great purity. Many medicinal springs occur, as at Thirsk, Croft, Knaresborough, and Ripon, Yorkshire; Gainsborough, Lincolnshire; Moreton and Wellington, Shropshire; Thornton, Nottinghamshire; Leamington and Newnham Regis, Warwickshire; and Tewkesbury, Gloucestershire.

The new red sandstone affords but few fossils, and those found consist chiefly of fragments of shells and the bones and teeth of reptiles, with the impression of footmarks of those or similar animals. The impression of ferns and other plants resembling those in the coal measures, have been found on the marly beds and silicified wood in the sandstone. The quartz pebbles which are extensively scattered through the sands of this formation sometimes afford impressions of shells, but these belong to older rocks. The footprints above alluded to are very remarkable, and nearly resemble the impression of a hand, though of a great variety of dimensions, and were probably made by animals of whose existence we have no other indication. In a rock corresponding with the new red sandstone,

in North America, have been found the footprints of wading birds of colossal dimensions, far exceeding any now in existence.

Extensive deposits corresponding with our new red sandstone occur in various parts of Europe and America, with which are associated deep beds of limestone.

MAGNESIAN OR CONGLOMERATE LIMESTONE.

This rock crops out from beneath the new red sandstone, and extends from the river Tyne, at Sunderland, to the neighbourhood of Nottingham, with a variable breadth seldom exceeding ten miles. It is a yellowish glimmering sub-granular limestone, containing about 20 per cent. of magnesia, and is the material used in the construction of York Minster and Westminster Hall, and from observations made upon its durability in those and other ancient structures, was selected for the erection of the new Houses of Parliament. The analysis of 100 parts of the stone of York Minster gave the following result:

Carbonic acid	47.
Lime	33.24
Magnesia	19.36
Iron and Clay	.40
	100.

The proportion of magnesia differs very much in other specimens, nor is it likely that it should be at all constant. It has a more sandy appearance than other limestones, and is often associated with conglomerate limestone of older rocks, varying from the size of large pebbles to

very fine grains. Though its general colour is yellowish or buff, it varies from almost white to a fawn or salmon colour, and is occasionally of a brown or reddish hue. Besides its use for building purposes, it is also used for forming steps and troughs for containing water, and though not sufficiently compact to deserve the name of marble, yet slabs of it are sometimes polished at the Sunderland quarries. When burnt to lime, it forms an excellent material for mortar, and is used also as a cement, which when mixed with bullock's blood is used for mending boilers. This lime is, however, unfit to be applied to the land in the large way, by reason of the magnesia remaining a long time caustic, in which state it is injurious to young plants. In small quantities it proves beneficial to most soils, and is conveyed from Sunderland to Scotland to be so applied. The lowest beds of this formation afford a blue stone, which produces lime of good quality, and is quarried at Bolsover, Encrife, Barborough, and Houghton, in Yorkshire. The upper beds in Nottinghamshire are often overlaid by thin beds of an exceedingly tough and retentive clay.

Magnesian limestone occurs overlying the coal near Whitehaven, connected with red marl of the vale of Carlisle, and also in Dumfriesshire, Scotland. Magnesian conglomerates were found in sinking for coal near Bath, and occur at Wick Rocks, north-west of Bath, resting in horizontal beds on the highly inclined strata of the coal measures and mountain limestone of the Gloucester and Somerset coal-field. These conglomerates occur also on the south of the Avon, and along the flanks of the Mendip Hills, of which one locality

is the remarkable cavern of Wookey Hole. In the north of England the magnesian limestone has, according to Professor Sedgwick, a thickness of 500 feet, and rests upon marly beds and bands of compact and shelly conglomerate limestone, and a sand rock called the lower new red sandstone, which by their conformity with the coal measures beneath, both in stratification and organic remains, cause them to be regarded as a distinct formation from the sandstone above, which is therefore called the upper new red sandstone. So marked is the difference of the fossils contained in the magnesian limestone, and the conglomerates and sandstone beneath, from those of the upper new red sandstone, as to cause the distinctive name of *Palæozoic*, signifying "ancient life," to be applied to them.

The relative position and character of these several strata in the north of England, are thus given by Professor Sedgwick:—

<i>Magnesian Limestone Series.</i>	{	Grey thin bedded limestone.
		Red marl and gypsum.
<i>Lower New Red Sandstone.</i>	{	Magnesian limestone, (Zechstein of the Germans,) a deposit attaining a thickness of 500 feet, often earthy but sometimes hard and crystalline.
		Marly beds associated with thin bands of compact and shelly limestone.
		Lower new red sandstone, (Rothe-todlehegende of the Germans.)

Sir R. I. Murchison has recently discovered that a formation strictly corresponding with our magnesian and lower red sandstone extends over 700 miles along the western flank of the Ural Mountains in Russia, and 400 miles between those mountains and the River Volga, to which he has given the name of the *Permian System*, from an ancient kingdom called *Permia*.

CHAPTER IX.

OLDER SECONDARY STRATA—THE CARBONIFEROUS SYSTEM.

Carboniferous System, geological character of—Coal Measures—Their localities—Structure and Organic Remains—Faults, or displacements—Extent of the British Coal-fields—Produce of the Mines—Coal-fields in Ireland and Scotland—Newcastle District—Choke and Fire-damp of Mines—Great Coal-field of Yorkshire—North Stafford—Newcastle-under-Lyne—Manchester and South Lancashire—Whitehaven—Ashby—Dudley and Staffordshire—Shropshire Coal-field—South Gloucester and Somerset—Great South Wales Coal-field—Coal-fields of Ireland—Foreign Coal Formations—Agricultural character of the Coal Measures—Water in Coal Mines—Thermal, Chalybeate, and Sulphureous Springs.

WE are now arrived at a stage in the descending series of the secondary rocks, which presents a very marked difference in their general character, but more especially with regard to the highly inclined position of most of the rocks, and the organic remains discovered in them. Owing to both these facts, but particularly the latter, geologists have distinguished them by the name of Palæozoic rocks (ancient life), in which class they have indeed included also the magnesian limestone and sandstone just described. This class, including all the remaining fossiliferous strata yet to be noticed, have been further distinguished by the terms upper, middle, and lower palæozoic.

Werner, the founder of the German school of Geology, observing that an extensive series of rocks, in that part of Germany in which he studied, lay conformably one over the other, and in nearly a horizontal position, denominated them *flætz* or flat rocks, and the term was once adopted in

England for all the rocks above the carboniferous system, where the same general disposition was observed, though with many exceptions. A more extended observation, however, has shown that this position of the strata could not be considered as a distinguishing characteristic anywhere, as in numerous instances these so-called flat rocks have been found to have every degree of inclination, doubtless owing to the changes which have since their deposition affected the rocks upon which they repose, and which we are now about to describe.

The carboniferous system of England may be represented in the following table:—

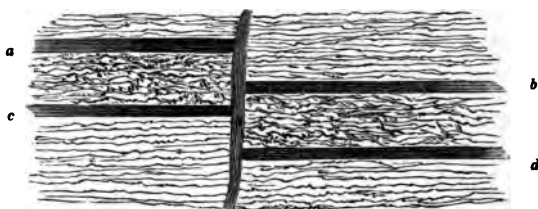
1. The coal measures with their grits and shales.
2. The millstone grit.
3. The carboniferous or mountain limestone.
4. The lower carboniferous shales.

COAL MEASURES.

These formations are extensively dispersed over the more northern and western part of our island, while to the eastward of a line drawn from the mouth of the Tees to the Island of Portland, no coal measures or any considerable deposits of coal occur. These strata are the next in order in the descending scale to the new red sandstone and the magnesian limestone before described, and consist of alternating beds of shale or indurated clay, sandstone, coal, and in many instances clay, iron ore, and limestone, resting for the most part upon a deep stratum of sandstone, or of mountain or carboniferous limestone. The beds of coal are *often* very numerous, varying from a few inches

to many feet in thickness; they are evidently of vegetable origin, as is manifest from examination of thin fragments of coal by the microscope, and also from the immense number of the impressions of a great variety of ferns and reeds which abound in the intervening beds of sand and shale, of which a large collection has been deposited in the British Museum; the whole belonging to species of plants now entirely extinct. It appears probable that these beds of coal were produced, for the most part, by the accumulation of beds of peat, often of great thickness, and by the transported masses of an exuberant vegetation, carried down from the land into lakes and estuaries, and successively covered up by drifted silty and sandy deposits, while the limestone, and the beds of iron ore, which some of these measures contain, must be referred to the same operations, both mechanical and organic, which produced them in the peat bogs, and in the seas and lakes of the present period. The fossil vegetable remains of the coal formations, wherever they are found, afford the most convincing evidence of a climate of equal, if not much higher temperature than that which now prevails in the intertropical regions, as the fossil reeds and ferns are of gigantic size, very far exceeding in dimensions any plants of a similar character which the hottest countries now afford, and must have been the production of an exuberance and rapidity of growth of which we can scarcely form any conception. Fossils of a similar kind to those found in our coal measures, were discovered by Captain Sir E. Parry, in one of his arctic expeditions, as far north as the 70th degree of latitude, which manifests, in an equally striking manner as the

discovery of the elephant in the ice of the river Lena, the great changes of climate which at remote periods have taken place upon our globe. The coal measures almost everywhere exhibit proofs of their having undergone great disturbance since their deposition and solidification, as they are rarely horizontal, and are generally highly inclined, and when covered up by the newer strata, the latter are found resting unconformably upon their steep sides or broken and upraised edges. In numerous instances these strata have been invaded by trap rocks, by which they have been penetrated, divided, and elevated, producing those dislocations called faults, by which beds once continuous have been separated sometimes many hundred feet from each other, causing often great perplexity and enormous expense to the miner. The following section will afford some idea of the nature of these faults:—



a The upper raised bed of coal. *b* The corresponding bed.
c Lower raised bed of coal. *d* The corresponding bed. *e* The fault.

The coal mines of Great Britain, taking them collectively, are the most productive of any in the world, and are the real solid foundation of her wealth, power, and political ascendancy. This support of her greatness appears to be almost

inexhaustible, even by the immense demand which is daily increasing, for domestic, manufacturing, and locomotive purposes. We have not before us any very recent calculations of the consumption of coals; but it appeared in evidence given by Mr. Buddle before a Committee of the House of Lords and Commons, in 1830, that the annual consumption of England and Wales only was as follows:—

Manufacture	3,500,000	chaldrons.
Household consumption } in the interior. . . . }	5,500,000	ditto.
Sent coastwise	3,000,000	ditto.

12,000,000, or 16,200,000 tons.

In the year 1828 the exports of coal from the Tyne and Wear were 3,200,000, and the consumption on the spot was estimated at 660,000 tons; so that the quantity of coals annually raised from this coal-field only amounted to nearly 4,000,000 tons.

Mr. Taylor estimates the quantity of coal contained in the Durham and Northumberland coal-fields to be 6,046,320,000 tons, which would supply such a consumption as that above given 1,500 years. Such calculations as the latter must obviously be very vague, and they have been disputed by the most eminent geologists. As, however, they are founded upon certain known data, they afford us sufficient assurance, notwithstanding the increased consumption since that period, that it will require many ages at least to exhaust this great mineral treasure, and that the decadence of Great Britain, so far at least as it depends upon the diminished production and failure of its mines, must be slow and gradual.

The principal coal-fields of the United Kingdom are the following:—

1. The south of Scotland, extending from sea to sea, and north and south of the Firth of Forth.
2. Northumberland and Durham.
3. Yorkshire, Derbyshire, and Nottinghamshire.
4. Whitehaven.
5. South Lancashire.
6. North Staffordshire and Potteries.
7. South Staffordshire and Warwickshire.
8. Shropshire fields, including Colebrook Dale and Shrewsbury.
9. Forest of Dean, Gloucestershire.
10. South Gloucestershire, or Bristol field.
11. Somerset.
12. North Wales.
13. South Wales.

To these must be added the limited fields of the north and south of Ireland.

The principal geological features of these coal-fields are the numerous alternating beds of sandstone, shale, limestone, and ironstone, which separate the seams of coal, and the great disturbance to which they have been subjected. In order to give a more perfect idea of these remarkable and important formations, we subjoin a short description of each of the principal of them, with occasional sections of the several beds of which they are composed.

In Scotland, the coal measures rest upon the old red sandstone, and occupy a considerable portion of a space of about 100 miles in length and 40 miles wide, extending from the German Ocean to the Irish Channel. Upon the old red sandstone rest similar beds with impressions of plants, and some thin beds of coal. To these sandstones succeed a number of thin beds of limestone, alter-

nating with others of sandstone and shale, and also of coal of no value; upon these rest thick limestone strata, upon which the valuable coal measures repose. The beds of which these productive measures are composed are very numerous, not less than from three to four hundred, of which upwards of eighty are coal. The total thickness is enormous, and is estimated at 5,000 feet. The iron ore they afford is of very superior quality, and the affluence of the south of Scotland, in these valuable minerals, has enabled it to extend its manufacturing operations, and to maintain a successful rivalry in several important branches with England.

The great Coal-field of Northumberland and Durham has been described by John Winch, Esq., in the fourth volume of the "Transactions of the Geological Society," and by Dr. Thompson, in the "Annals of Philosophy," from which sources the following particulars, by the Rev. W. D. Conybeare, have been derived:—"The *coal measures* of this field commence near the river Coquet on the north, and extend nearly to the Tees on the south. The length of this tract is about fifty-eight miles, and its greatest breadth about twenty-four. The strata of the mill-stone grit pass under those of the coal measures; which latter pass beneath the magnesian limestone, the northernmost point of which is near the mouth of the river Tyne. The strata of this, as of many other coal-fields, appear to dip from the surface; so that a section of them gives the idea of the form of a boat. A place called Jarrow, which is about five miles from the mouth of the Tyne, and on its southern branch, is the spot beneath which the beds of coal in the

coal measures are found at the greatest depth. One of the thickest beds, called the *high main*, is 960 feet below the grass at Jarrow, and rises on all sides; but as the dip of the strata, which averages one in twenty, is not uniform in every part in the surrounding district, the bed does not rise to the surface at equal distances around that place. We may assume that Jarrow is the centre of the coal measures, since it is the spot beneath which the high-main coal is found at the greatest depth beneath the surface. There is a considerable, though not perfect uniformity in the distance of the several coal beds from each other. Hence, as the high-main coal rises to the surface of the alluvial soil around Jarrow, we may conclude that the beds above and below the high-main arise also at a distance from it proportionate to their depth beneath it.

“The inequality of the surface does not affect the dip or inclination of the strata constituting the *coal measures*; so that when they are interrupted, or cut off by the intervention of a valley, they will be found on the sides of the opposite hills at the same levels as if the beds had once been continuous. The conclusion is obvious, that the present irregularities of hill and dale have been occasioned by the partial destruction or dispersion of the uppermost strata constituting the coal formation. The beds of coal and other strata composing the coal measures are not everywhere of uniform thickness; they occasionally enlarge and contract so greatly, that it is only by an extensive comparison of the whole series that any certainty is arrived at of that general uniformity of stratification which is known actually to exist. From

the best information, they are calculated at 1,620 feet in thickness.

“The beds of coal, &c. basset out one after another at the surface, each on the *east* of that which immediately precedes it in point of age. These beds are sometimes visible, but are more commonly covered by alluvial soil. This alluvium contains masses of the different rocks composing the whole district, and amongst them portions of hard black *basalt* are found everywhere in abundance. From this stone the ancient inhabitants of Britain formed the heads of their battle-axes, which are commonly called celts, which resemble in shape the tomahawks found in the South Sea Islands. Barbed arrows, neatly finished, and made of pale-coloured flint, are frequently picked up on the moors, and are called *elf-bolts*. This alluvium also contains portions of trap-rocks of the Cheviot range, and masses of fine grained gravel appear on the surface of the whole country. The whole surface of the coal measures is calculated at 130 square miles. The greatest number of the numerous mines are situated on both sides of the river Tyne, but are not far distant from its banks. There are several in the northern part of the district, and many about five miles south of the Tyne, midway between Newcastle and Durham.

“In the coal measures, forty beds of coal have been seen, but a considerable number of these are insignificant in point of thickness; the two most important beds are those distinguished by the names of *high main* and *low main*. The thickness of the first is 6 feet, of the second 6 feet 6 inches. The high main is about 60 fathoms above

the low main, which latter is, at St. Anthony's Colliery, not far from Newcastle, 135 fathoms from the surface. Between them occur eight beds of coal, one of which is 4 feet thick, another 3 feet thick. Seven beds have been seen under the low main, but the quality is inferior, and more nearly approaches that of the millstone grit and shale series.

Mr. Winch states, that in Biggs's Main colliery, the sinkings continued to the depth of 1,158 feet, of which he gives the following particulars:—

	Feet	In.
From the surface of the ground clay	102	0
Sandstone	42	6
First seam of coal	0	8
Twenty-nine beds of sandstone and shale, varying in thickness from 40 inches to 31 feet, interstratified with eight seams of coal, from 5 to 8 inches thick, altogether	418	2
The high main coal	6	8
Fifty-two beds of sandstone and shale, varying from 5 inches to 34 feet in thickness, inter- stratified with nineteen different seams of coal, from 2 to 37 inches in thickness, amounting together to	503	2
The low main of coal which here is only	2	9
Beneath this the sinkings continued through ten different beds of stone, from 12 inches to 12 feet thick, and two seams of coal of 4 and 12 inches, making together	82	0
	1,158	0

The excellence of the coal is well known, a principal cause of which is the small quantity of earthy or incombustible matter it contains, which is stated to be not more than 1 per cent.

Some years ago, a practice was adopted, when the coal was of a fragile nature, of erecting screens for separating the smaller from the

sounder coal. This system is now become universal; and immense heaps of refuse small coal are raised at the mouths of the pits. These soon take fire from the heat of the decomposing pyrites, and continue to burn for several years. Not less than 100,000 chaldrons are thus annually destroyed on the Tyne, and nearly an equal quantity on the Wear. The beds of coal beneath have been known to take fire; and it is recorded in the history of Northumberland, that about 140 years ago, the high main coal took fire and burnt for 30 years.

The *choke-damp* and *fire-damp* frequently occur in these mines, and cause great destruction of life. The coal appears to part with a portion of carburetted hydrogen (inflammable gas) when newly exposed to the atmosphere; a fact rendered probable, by the well-known circumstance of the coal being more inflammable when fresh from the pit than after long exposure. The pyritous shales that form the floors of the coal mines, decompose the water that lodges in them; and the process is constantly operating on a large scale, in the extensive waste of the old mines. In whatever mode we suppose the gas to be generated, it is disengaged abundantly from the high main coal seam, but more particularly from the lower main, and with a rapidity that is truly astonishing. It is well known that the gas frequently fires in a shaft long before the coal seam is reached by the sinkers; and that the pitmen occasionally open with the pick crevices in the coal or shale, which emit 700 hogsheads of fire-damp in a minute. These blowers, as they are termed, continue in a state of activity for many months together, and

seem to derive their energy from communicating with immense reservoirs of the same inflammable air. All these causes, unfortunately, are united in the deep and valuable collieries, situated between the great north road and the sea. Their air-courses are 30 or 40 miles in length; and here, as might be expected, the most tremendous explosions ensue. The after-damp or *stythe*, which follows the blast, is a mixture of carbonic and azotic gases, resulting from the combustion of the carburetted hydrogen in atmospheric air; and more lives are destroyed by this than by the violence of the fire-damp. Various means have been resorted to for the prevention of the disasters consequent upon this state of the mines, which destroys hundreds of lives; but none of the means employed proved effectual till the invention of the safety-lamp by the late Sir H. Davy, by the careful use of which the miner can pursue his labours in the worst mines with little or no danger from the inflammable gas. The danger arising from the choke-damp can only be prevented by ventilation, to effect which, powerful mechanical means are employed to drive or draw air down the shafts and along the galleries of the mines.

The sandstone of these coal measures is called *post* by the miners, and when very hard is called *whin*, the same term given to basalt. A thick bed of sandstone on the south of Newcastle, called Gateshead Fell, produces the celebrated Newcastle grindstones, while the softer part of this bed, which is sixty-six feet thick, is used for filtering-stones. In these measures, beneath the surface soil, potters' clay is found, of a blue or grey colour, and sometimes yellowish or orange, which

used in the manufacture of coarse pottery, tiles, and bricks. The shales beneath afford thin beds of nodules of clay-ironstone, with lead-ore and pyrites; the latter is dispersed in great abundance through the beds of coal and shales, and it is this mineral which causes by its decomposition the spontaneous ignition of coal, when heaped together in large quantities, and is often the cause of disasters at sea.

The organic remains of this formation consist of impressions of plants, including a variety of ferns, and a plant resembling a cane. In one of the sandstone strata, called firestone, a fossil tree was discovered twenty-eight or thirty feet in length, the trunk and larger branches of which were siliceous, while the bark, the small branches, and leaves were converted into coal. This alone affords a sufficient proof of the vegetable origin of all the great masses of the beds of coal. The small veins of coal called by the miners *pipes*, probably owe their origin to small branches of trees. Bivalve shells are found, resembling those of the fresh-water mussel, in a dark grey ironstone, and in the black shale, at the depth of 780 feet from the surface.

Those dislocations called *faults* occur in this coal-field to a great extent; the strata are often separated by fissures extending to an immense depth, in a nearly perpendicular direction, attended with depressions and elevations of the divided parts, which remove those parts to great distances in a vertical or perpendicular direction, sometimes amounting to several hundred fathoms. These fissures or rents in the rock are filled up with various substances, but generally with sandstone,

and not unfrequently with trap-rock. When these faults are considerable they are called *dykes*, and those of less magnitude *slips* or *troubles*. In the *great main* of this formation there is a remarkable dyke, called the ninety-fathom dyke, from the beds on the northern side being ninety fathoms lower than those on the southern side. This dyke is nearly vertical; in some places its width is not great, but in Montague Colliery it is twenty-two yards wide, and is filled with hard and soft sandstone. These faults are a source of great trouble and expense to the miner, by lifting the strata out of their level, and filling the mines with water and fire-damp; they, however, often prove beneficial, by elevating the strata of coal, which would be otherwise inaccessible; and when the matter with which the crevices are filled is impervious, they afford facilities for working the mines, by keeping back the water, or throwing it out in springs.

Our limits will not allow us to dwell with so much particularity on the other coal formations, which indeed is the less needful as they all more or less resemble each other in their principal characteristics.

The great Coal-field of South Yorkshire, Nottingham, and Derbyshire extends from Leeds to Nottingham, in length about sixty miles, with a mean breadth of about twelve miles, its greatest breadth not exceeding twenty-two. The strata of this formation range from north to south, and dip to the east under the magnesian limestone, and rising to the west and north-west, they are seen to crop out upon the millstone grit, which supports the *northern coal-fields*. This coal deposit exhibits

numerous beds of gritstone, shale, bind, and clunch, alternating with many beds of coal, of different thickness, the whole reposing upon the millstone grit, below which no workable coal is found. The beds of shale consist of slaty argillaceous substances, generally of a brown or black colour, some of which contain masses of clay-ironstone, which in one place is remarkable for abundant impressions of mussel-shells, and is worked as an ornamental marble. The iron-ore is found in beds called *binds*. Some of the hard black binds are used as black chalk. Clunch is indurated clay, and yields the infusible kind which is adapted for making fire-bricks. In the whole of this field there are thirty different beds of coal, varying from six inches to eleven feet thick, and the total thickness of coal is said to be twenty-six yards. Every kind of coal occurs in this field, from the hard stone coal to the inflammable cannel coal and the peacock coal, and several of the beds are of excellent quality for domestic use. The field is traversed by an immense fault, which has disturbed and dislocated the beds of coal very much. To the east, coals underlie the magnesian limestone, and are worked through it.

Of the *Coal-fields of North Stafford*, one is at Cheadle and the other at Newcastle-under-Line. The former, according to Mr. Farey, consists of an insulated basin of the lower members of the coal measures reposing upon the millstone grit.

The Coal-field of Newcastle-under-Line occupies a triangular space, whose boundary lines extend from seven to ten miles. The strata of this formation have a considerable inclination, dipping from opposite sides towards the centre, with a

descent of one foot in four. It has been ascertained in one locality to have thirty-two beds of coal, varying in thickness from three to ten feet each. On the north-east and north-west, this coal-field is bounded by the millstone grit, which crops out from beneath it.

The Manchester, or South Lancashire Coal-field, occupies also a small part of the north of Derbyshire, and extends from east to west, in a curved line, upwards of fifty miles, with a mean breadth of about ten miles, comprising a most important tract, as affording fuel for domestic purposes to two of the greatest cities of the empire, Liverpool and Manchester, and the means of propelling the most accomplished machinery that the inventive genius of man has ever devised—perhaps more productive of comfort to distant nations than to those whose skilful hands conduct its wonderful operations.

The strata of this field have been much disturbed by faults, having a highly inclined, and in one place a vertical position, but are very rich in coal, as in one district more than fifty seams occur within a few hundred yards of sinking. On the east, west, and north, this valuable coal-field reposes on the millstone grit, and on the south is covered over by the new red sandstone. A small isolated coal-field occurs to the north of the great field.

The Whitehaven Coal-field extends about forty miles in length, with a variable but inconsiderable breadth, and reposes upon the mountain limestone on the south and east; on the west it occupies the sea-shore, and is bounded on the north by the magnesian limestone and the new red sandstone

the vale of Carlisle. To the north and east of latter place, within the depth of 165 fathoms, y work seven large beds of coal, which are n four to ten feet thick, with a dip of one d in ten. The faults, which run east and st, have shifted the strata 120 feet perpen- ular. To the south-west of Whitehaven, enteen beds of coal are cut through, and the eenth and seventeenth respectively have a ckness of five and eight feet; the former is arated from the latter by twenty-four beds of te ironstone, with one thin bed of coal.

The Ashby Coal-field is of inconsiderable extent, t important for its productiveness. It consists two small detached basins. Between the vil- es of Bretby and Swepstone more than twenty ul-works have been opened; the deepest of these sunk 246 yards, and one of the coal-beds pene- ted has the great thickness of seventeen to enty-one feet. The following is the section of it in this line belonging to Lord Moira, which of very interesting character.

	Ft.	In.
Various strata of bind (indurated clay), occasionally containing ironstone . .	53	7
Coal	3	0
Bind, &c.	128	0
Coal	3	4
Bind	177	7
Coal	4	10
Bind	46	9
Kennel coal	2	9½
Bind, &c.	128	0
Rider coal	5	5
Fine clay	3	0
Coal	15	0
	571	3½

There appears to be no millstone grit underlying this coal-field, as in the more northern fields; but mountain limestone appears in detached masses on its northern boundary.

The Warwickshire Coal-field extends from near Coventry, in a north-west direction, to Tamworth, with an average breadth of about three miles. All the strata rise to the east-north-east, at a great angle to the horizon, exhibiting at the out-crop in some places the strata of the coal measures, and in others the millstone grit. The principal coal-works are at Griff and Bedworth; at the former, four beds of coal are worked, the principal one being three yards in thickness, and the workings are 117 yards deep. The underlying millstone grit is a compact and flinty sandstone, which in one place rises from beneath the coal-field at an angle of 45° .

Dudley and South Staffordshire Coal-field extends about twenty miles in length, in a south-west and north-easterly direction, from Stourbridge to Beverton, with a breadth at Dudley of about four miles. Its surface has been accurately ascertained to be equal to sixty square miles. The northern portion affords many coal seams from four to eight feet thick. The southern portion, extending to Stourbridge, seven or eight miles in length, and four in breadth, contains a coal-bed of the extraordinary thickness of thirty feet, locally called the Ten-yard Coal, which far exceeds that of any other seam in the British coal-fields. Strictly speaking, however, this depth of coal consists of several beds, lying one upon another, and some of them separated by very thin beds of clay, called *partings*. The beds which intervene between the

several seams of coal consist principally of shales or slate clay, locally called clunch, and sandstone, with a few beds of clay and ironstone.

Dr. Thompson gives the following section of the different beds bored through at Bradley Colliery near Bilston:—

	Yds.	Ft.	In.
Soil of the surface	0	2	0
Red sand	10	0	0
Slate clay	8	0	0
Sandstone	1	0	0
Slate clay	6	0	0
Sandstone	1	0	0
Ditto	0	2	0
Slate clay	0	1	6
Sandstone	0	1	0
Slate clay, with four thin beds of ironstone	4	0	0
Slate clay	3	0	0
Shale	0	2	0
Coal	1	2	0
Shale	1	1	0
Slate clay	1	2	0
Clay ironstone	0	0	8
Shale	0	2	6
Coal	8	1	3
Clay	0	1	6
Slate clay	0	0	6
Slate clay	0	2	0
Clay ironstone	1	0	0
Shale	0	1	0
Coal	0	0	6
Shale	0	2	0
Slate clay	3	1	0
	56	2	5

Some years ago Lord Dudley cut an underground canal to his limestone quarries near Dudley; in the course of which undertaking all the coal-beds between the limestone and the ten-yard coal were cut through. All the coal-pits in the

county go as low as the ten-yard coal, in which their great workings always exist; hence all the different beds which constitute the coal formation in this place have been cut through, and are well known. The following are the beds passed through in cutting this canal and a coal work in the parish of Rowley, worked by Mr. Keir, commencing with the lowest beds:—

	Yds.	Ft.	In.
1. Slate clay	30	0	0
2. Limestone	10	0	0
3. Slate clay	76	2	0
4. Coal	0	2	0
5. Slate clay	40	0	0
6. Coal	5	0	0
7. Slate clay	2	2	0
8. Coal	3	1	0
9. Gravel	2	0	0
10. Coal	3	0	0
11. Slate clay	9	0	0
12. Ditto	2	0	0
13. Heathen coal	2	0	0
14. Slate clay and ironstone	7	0	0
15. Coal	10	1	6
16. Bituminous shale	0	0	7
17. Slate clay	0	2	9
18. Coal	0	0	10
19. Bituminous shale	2	0	0
20. Slate clay with ironstone	0	2	9
21. Sandstone	2	2	10
22. Slate clay	1	1	0
23. Coal	0	0	9
24. Slate clay	0	0	10
25. Sandstone	1	1	0
26. Sandstone with coal	1	1	0
27 and 28, Sandstone	6	2	0
29. Slate clay	4	2	0
30. Sandstone	5	2	0
31. Slate clay and ironstone	0	2	9
32. Slate clay	8	2	0
33. Ditto, with ironstone	2	1	0
34. Coal	0	1	3
35. Slate clay	2	1	0
36. Coal	0	0	9

	Yds.	Ft.	In.
37. Slate clay	0	1	0
38. Sandstone	2	1	0
39. Shale, emitting fire-damp	0	0	3
40. Sandstone	0	2	0
41. Ditto	0	2	0
42. Slate clay	4	0	0
43. Ditto	1	1	0
44. Coal	0	1	6
45. Clay	2	2	0
46. Slate clay	4	0	0
47. Ditto, with ironstone	3	2	2
48. Sandstone	2	2	0
49. Clay with coal	0	0	3
50. Sandstone	0	1	0
51. Slate clay	5	1	8
52 and 53, Ditto	5	3	6
54. Sandstone	1	1	0
55, 56 and 57, Slate clay	17	1	0
58. Clay mixed with coal	0	0	10
59. Slate clay with ironstone	2	2	3
60. Sandstone with some coal intermixed	1	2	0
61. Slate clay	1	2	0
62. Clay	0	1	0
63. Slate clay	2	0	0
64. Red clay	1	2	6
65. Surface soil	0	1	0
Total thickness	313	1	3

We have been particular in quoting the details of these sections, as they exhibit the structure of a coal-field of unparalleled mineral riches, for, besides a great quantity of ironstone, there are eleven beds of coal, whose united thickness is twenty-seven yards, or seventy-one feet. The interstratifying beds chiefly consist of slate-clay in the place of the sandstone of the northern coal-fields.

The quantity of coal raised in this field is prodigious; for, to the immense quantity carried away for the manufacturing and domestic pur-

poses of Birmingham, Wolverhampton, Stourbridge, and other towns, and a large part of the midland counties, must be added the enormous consumption of the numerous blast-furnaces and forges, the blazing fires and thundering sounds of which astonish the belated traveller who for the first time crosses this district after nightfall.

In some of the coal-pits of this district there are vast quantities of small fragments of coal; these are left in the mine, as, from the cheapness of coal, they are not worth the expense of removal, and they are said to amount to one-third of the total quantity, while, another third being left for pillars, immense waste is committed, the effect of the abundance of the material.

On the west of Dudley there is a considerable tract where the coal has taken fire from spontaneous ignition many years since, and still continues burning. Smoke and steam may in some places be seen to rise; the vegetation of the surface is more active, and the water of the ponds becomes warm, and, what is very remarkable, the clayey strata covering the ignited coal have been converted by heat into a species of porcelain jasper, beautifully striped by the various degrees of oxidation induced on the iron it contains; thus affording a type, upon a small scale, of those changes produced upon rocks in the great operations of nature, by which soft shaly strata have been converted into crystalline rocks, and coarse limestone into granular marble.

Shropshire Coal-fields.—The plain of Shrewsbury, through which the Severn flows from that city, is generally occupied by the new red sand-

stone, with occasional patches of coal formation of inconsiderable extent. To the south of the Wrekin Hill, a remarkable trap formation which rises from this plain, the Severn flows through the important coal-field of Coalbrook Dale, which is very rich both in coal and iron, and has been extensively worked at Madely, Old Park, and Ketley, for the supply of the iron-works at the latter place and at Coalbrook Dale. This formation consists of numerous beds of sandstone, slate-clay, and indurated clays, alternating with beds of coal and ironstone, with the important addition of a band of limestone, which indicates that this formation is of fresh-water origin. The whole of these beds are said to repose on a limestone formation, probably the Silurian. At Madely they have been sunk through to the depth of upwards of 700 feet. The beds of coal are numerous, varying from a few inches to five or six feet thick. A mineral tar flows from these beds at Coalport, on the banks of the Severn. The extensive works at Coalbrook Dale had the honour of producing the first iron bridge, which was there erected over the Severn in the year 1777, since which time another iron bridge has been thrown across the same stream at Bildwas Abbey, about a mile above the former. Both of these bridges span the Severn with one arch.

There are other coal formations to the south, in the same county, of which we shall only notice those of the Clee Hills. These afford ironstone, as well as coal, and that peculiar kind of the latter called cannel coal, which is frequently wrought into ornaments of various kinds. The most important of the beds of coal is covered by basalt,

which forms two irregular ledges above it. Coal is also worked at Billingsby, to the west of these hills, which gave rise, about fifty years ago, to an abortive attempt to establish iron-works there; and a stinking coal is obtained near the banks of the Severn in the neighbourhood.

The Coal-fields of South Gloucester and Somerset are remarkable for the disturbance the strata have undergone, and the thinness of those which overlie and rest unconformably upon them. At Paulton, a village near Bath, a shaft has been sunk through the inferior oolite, the lias, the new red sandstone, and magnesian limestone, into the coal measures. The latter contain numerous thin beds of coal, scarcely any of them above a yard thick. This coal is of the caking, or bituminous kind, and leaves when burnt a great quantity of a reddish ash. The lower beds are separated by shales, and are divided from the upper by the pennant-grit rock, which, owing to its extreme hardness, is exceedingly expensive to penetrate. The fractures in the coal-beds of this field often exhibit beautifully-white crystal veins of carbonate of lime intersecting and ramifying through the black mass.

The great South Wales Coal-field extends from Pontypool on the east, to the Bay of Caermarthen on the west, a distance of between fifty and sixty miles, with a medial breadth of about twenty miles north and south, having the Bristol Channel for its southern boundary. This great formation of coal appears to be situated in a basin of mountain limestone, which crops out from beneath its northern border, and extends from sea to sea on the east and west. It contains numerous beds of

coal, varying in thickness from six inches to nine feet. Twenty-three of these beds have an aggregate thickness of ninety-five feet, and it is estimated that a square mile will produce 64,000,000 tons of coal. Now, if we consider that there are only 100 square miles capable of such production, it would appear to be almost inexhaustible. Near Caermarthen Bay, however, the coal-beds are much shallower. The coal on the north side has the property of caking, and is well adapted for domestic purposes; while the strata to the westward afford anthracite or culm, which is largely used in the manufacture of iron and for burning lime. In the lower part of this coal-field the coal-beds are interstratified with shaly beds; but those of the upper consist of very hard grit-stone, called pennant by the Somerset miners. These beds are often laminated, and divided into thin plates, so as to be used for tiling and flagstones. This formation appears to be equally rich in clay-ironstone as in coal, of which, in one part, it contains sixteen beds; these principally occur in the lower series of strata, as at Merthyr Tydvil; and some of the most valuable extend below the coal.

The deep valleys which traverse this coal-field from north to south, afford the miner a facility of obtaining the coal and iron-ore at little comparative expense, by means of levels and tram-roads, owing principally to which, manufactured iron is produced at a less cost than in any of the English iron and coal districts. This field is traversed by dykes and faults, chiefly in a north and south direction, which have broken and shifted the strata from 50 to 100 fathoms up or down. An enormous fault, many fathoms thick, has effected

a rise in the strata of 240 feet. On the south side of this basin the inclination of the strata is sometimes 45° , and on the western termination, at Bride's Bay, the utmost distortion prevails, so that the beds are rendered vertical and twisted in every direction. The collective strata are of great thickness, as a little to the west of Neath the lowest strata of coal are 700 fathoms lower than the out-crop of the upper beds upon the hills, which affords a striking instance of the extent of these deposits, and the change in level which they have undergone.

Though what is called the carboniferous system is more extensively developed in Ireland than in either England or Scotland, yet the actual coal measures are of limited extent. Two of these are in the north, namely, in Connaught and Ulster, which produce bituminous coal, and that of Connaught is said to be remarkably well adapted to the production of iron and the uses of the foundry; as the grey pig-iron produced at the Arigna iron-works is said to be the best in the empire. The Ulster coal-works are but of little importance: the district commences at Dungannon, in the county of Tyrone, and extends in a northerly direction to Coal Island, and to the neighbourhood of Cook's Town. Mr. Weaver gives the following description of the collieries of Bally Castle, in the county of Antrim:—"These collieries have been wrought for a number of years. The coal is of a slaty nature, and greatly resembles both the coal and the accompanying rocks which occur in Ayrshire, and probably belongs to the same formation."

A very extraordinary discovery was made at

these collieries about the year 1770, which is thus described by the Rev. Dr. Hamilton, in his Letters on the North Coast of the County of Antrim:—“The miners, in pushing forward an adit or level towards the bed of the coal at an unexplored part of the Bally Castle Cliffs, unexpectedly discovered a passage cut through the rocks; this passage was very narrow, owing to incrustations formed on its sides. On being sufficiently widened, some workmen went through it. In minutely examining this subterranean wonder, it was found to be a complete gallery, which had been driven forward many hundred yards into the bed of coal; it branched out into thirty-six chambers, where coal miners had carried forward their works. These chambers were dressed quite square, and in a workmanlike manner; pillars were left at proper intervals to support the roof; and, in short, it was found to be an extensive mine, wrought by a set of people at least as expert as those of the present generation. Some remains of the tools, and even of the baskets used in the works, were discovered, but in such a decayed state, that, on being touched, they fell in pieces. Some of the tools appear to have been of wood, thinly shod with iron. The great antiquity of the work is evident, from the fact that there does not exist the most remote tradition of it in the country, but is more strongly demonstrable from the sides and pillars being covered with sparry incrustations, which the present workmen do not observe to be deposited in any definite portion of time.”

The coal formation of Leinster is situated in Kilkenny, Queen's County, and county of Carlow, and extends to the county of Tipperary. The

district is divided into three parts, separated from each other by mountain or carboniferous limestone, which also passes under the whole district. The Munster coal-measures occupy a considerable portion of Limerick and Kerry, and a large part of the county of Cork. Coal and culm are raised near Kanturk in the county of Cork, which have been highly beneficial to the agricultural and commercial interests of that part of the island. In the Munster district, at an angle of forty-five degrees, in the Dromagh Colliery four beds have been wrought; the first of these, which is the principal bed, is stone-coal three feet thick. These beds are known by the names, *coal bed*, *rock coal*, *bulk bed*, and *bath bed*. The coal bed consists of three feet solid coal, and is not sulphureous; the rock bed is nearly of the same thickness, and is very sulphureous; the other beds are of the culm species, but of peculiar strength, each barrel of culm sufficing to burn nine or ten barrels of lime. The workings are not deep, not exceeding eighty yards, and are much incommoded by water.

Coal measures occur in many parts of the Continent, and we may particularize those of France, Belgium, Spain, and Russia, which resemble in general character those of England. The coal-field at St. Etienne, between the Loire and the Rhone, is remarkable for its fossil trunks of trees, which are exhibited by an open working, as standing almost erect, and having the appearance of a petrified forest, as the beds are nearly horizontal. Many small basins of coal measures occur in the south of France. The coal measures of Belgium have undergone the greatest disturbance and depression. Baron Humboldt, in his admirable

work, "The Cosmos," speaking of the changes of level which the strata have undergone, quotes the following observations from Von Decken: "The depth of the coal basin of Liege at Mount St. Gilles, which I have ascertained to be 3,890 feet below the surface, extends 3,464 feet below the level of the sea, for the absolute height of Mount St. Gilles certainly does not much exceed 400 feet. The coal basin is fully 1,865 feet deeper. But all these depths are trifling when compared with those which are presented by the coal strata of Saar Rivier (Saarbruchen). I have found, after repeated examinations, that the lowest coal stratum which is known in the neighbourhood of Duttmeller, near Bettingen, must descend to depths of 20,682 and 22,015 feet below the level of the sea."

In Spain, coal occurs in Catalonia, Aragon, and New Castile. In the north of Russia coal is found on the banks of the Volga, where the beds or strata which contain it have a depth of 8,000 feet, but the number of workable seams is not more than eight, which afford coal of very good quality. In the south, good bituminous coal and also anthracite are obtained. The northern beds are nearly horizontal, while those of the south have been much disturbed by faults. In North America a large portion of the valley of the Mississippi is occupied by strata of the carboniferous series, said to extend about 900 miles from north to south, in which coal occurs in many places; and in all probability when that country has been thoroughly explored for its mineral wealth, immense deposits will be found. On the eastern side of the Alleganny range, in the north of

Pennsylvania, the coal measures consist of some hundred feet of sandstone and shale, and contain fourteen or fifteen beds of coal or anthracite, which have a total thickness of seventy or eighty feet. One of these beds is said to be about thirty feet thick, including some interstratified shale, but eighteen feet only of it are worked.

In Nova Scotia a remarkable development of coal strata occurs. These are composed of sandstone and shales alternating with seams of coal, iron-stone, and clay. These beds range for two miles along the coast, and contain numerous trunks of trees, which pass through different strata of shale and sandstone, but more of coal, and are abruptly broken off at various heights; they occur at different levels, and are always perpendicular to the strata in which they are found. There are about nineteen seams of coal, none of which exceed about eight feet in thickness. These strata exhibit the most astonishing phenomena of coal formations presented to our sight without labour, which perhaps anywhere exist.

Coal has been found in many parts of the East, and has been recently discovered in the island of Borneo, in the Indian Archipelago. The soils of the coal measures mostly consist of dark-coloured clays, and are generally unfavourable to agriculture in their unimproved state, from the too great retentiveness and prevalence of surface water. Draining and liming, with other resources of skilful cultivation, are therefore requisite to render them remunerative. When the outcrop of successive strata of shale and sandstone occurs, which is not unfrequent in the coal measures, the

elements of a good soil are present, and each may be improved by a mixture with the other. In their natural state, the soils of coal-fields generally present the two extremes of tenacious clay and porous sand, both of which demand alike enlightened skill and industry on the part of the husbandman. The colour of these soils is the most favourable feature they possess.

Water is generally to be found in the coal measures at no great depth, owing to the frequent alternations of shales and sand rocks; and this condition of the strata, and the faults which so frequently occur, serve to collect the water and to throw it out in springs. If *faults* cause perplexity and trouble to the miner, they frequently make him compensation by enabling him to conquer a still more formidable enemy, water; as the spaces or crevices of the faults are mostly filled up with clay, which confines the lateral movement of the water, and thus enables the miner to drain limited portions of the coal-field with greater facility. Salt springs sometimes occur on the coal measures, as at Ashby-de-la-Zouch; and in Gloucestershire, chalybeate and sulphureous waters are common; and a thermal chalybeate spring rises about six miles from Cardiff, in the bed of a river.

CHAPTER X.

Mill-stone Grit—Range and extent—General character—Description of in the North of England.—Iron, Copper, and Lead Veins—Organic Remains—Agricultural character.—Carboniferous or Mountain Limestone—Different Localities of—Thickness—Marbles of Kilkenny and Derbyshire—Black and variously coloured Marbles—Organic Remains—Structure and chemical character—Caverns and Clefts in—Beautiful character of the Scenery in Mountain Limestone Districts—Caverns—Subterranean Rivers—Metallic Veins—Organic Remains—Copious Springs—St. Winifred's Spring—Holywell—St. Ormond's, St. Mary's, and Cheddar Springs—Hot Springs of Buxton, Matlock, and Clifton.—Old Red Sandstone, or Devonian System—Extensive Distribution of—Character of its materials—Organic Remains—Elevation—Remarkable tracts of, in Scotland—Rocks of this System in Somerset, Devon, and Cornwall—Mineral products—Agricultural character.

MILLSTONE GRIT.

THIS formation, which may be considered as the middle member of the carboniferous series, extends from Ashbourne in Derbyshire to the mouth of the Coquet in Northumberland, forming a high central range of hills called the Pennine chain, and in conjunction with the carboniferous limestone, the next rock beneath, occupying a large space in the counties of Derby, York, Westmoreland, Durham, and Northumberland, and underlying all the great northern coal measures. It also underlies and surrounds the coal measures of the north and south of Ireland, and a large portion of the south-west on either side the estuary of the Shannon, in the counties of Clare, Limerick, Kerry, and Cork.

Though the prevailing and distinguishing cha-

racter of this formation is that of a coarse-grained gritty sandstone, much resembling the sandstones of the coal measures, it contains numerous beds both of shale and limestone, and in some places of coal; so that it partakes in a great measure of the character of the formations above and below it. In the north of England, indeed, the lines of distinction between this and the mountain limestone become much confused, and are lost in each other. As Professor Sedgwick has described this formation in his usual discriminating and masterly manner, we cannot do better, for the information of the reader, than by adopting his own words:—"On the reappearance of the carboniferous limestone at the base of the Yorkshire chain, we still find the same general analogies of structure: enormous masses of limestone form the lowest part, and the rich coal-fields the highest part of the whole series; and we also find the millstone grit occupying the intermediate position. The millstone grit, however, becomes a very complex deposit, with several subordinate beds of coal, and is separated from the great inferior calcareous group (known in the north of England by the name of the *scar limestone*), not merely by the great shale and shale limestones, but by a still more complex deposit, in some places not less than 1,000 feet thick, in which four groups of limestone strata, extraordinary for their perfect continuity and unvarying thickness, alternate with great masses of sandstone and shale containing innumerable impressions of coal plants, and three or four thin seams of good coal extensively worked for domestic use. In the range of the carboniferous chain, from Stanmoor through the ridge of the Cross Fell to

the confines of Northumberland, we have a repetition of the same phenomena. On its eastern flank, and superior to all its component groups, is the rich coal-field of Durham. Under the coal-field, and in a regular descending order, the millstone grit, the alternation of limestone and coal measures, nearly identical with those of the Yorkshire chain, and at the base of all is the *scar limestone*. The latter, however, begins to be subdivided by thick masses of sandstone and carbonaceous shale, of which we had hardly a trace in Yorkshire, and gradually passes into a complex deposit not distinguishable from the most superior division of the series. Along with this gradual change is a greater development of the inferior coal beds alternating with the limestone, some of which, on the north-eastern skirts of Cumberland, are three or four feet in thickness, and are now worked for domestic use, with all the accompaniments of railroads and steam-engines. The alternating beds of sandstone and shale expand more and more as we advance towards the north, at the expense of all the calcareous groups, which gradually thin off and cease to produce any impress on the features of the country. And thus it is that the lowest portion of the carboniferous system, from Bewcastle Forest along the skirts of the Cheviot Hills to the valley of the Tweed, has hardly a single feature in common with the inferior part of the Yorkshire chain, but on the contrary, has all the most ordinary internal character of a coal formation. Corresponding to this change is also a gradual thickening of carbonaceous matter in some of the lower groups. Many coal works have been opened upon this line, and

near the right bank of the Tweed (almost on a parallel with the great scar limestone) is a coal-field with five or six good seams, some of which are worked, not merely for the use of the neighbouring districts, but also for the supply of the capital. It appears, therefore, difficult, and almost impossible to preserve the millstone grit as a separate formation, as its assigned place between the coal measures and the carboniferous limestone, is in so many cases occupied by one or both of the latter."

The shales of this series contain masses of clay ironstone, similar to those in the coal measures, which sometimes have the character of septaria or cement stones. Lead veins occur in Derbyshire and Northumberland, but are said to be thin. The copper mine of Ecton, in Staffordshire, is situated in the limestone of these shales. Iron pyrites is also abundant, and naphtha and asphaltum occur in the shales of Derbyshire, the result of the decomposition of coal by the action of heat. The organic remains of this formation appear to be similar to those found in the coal measures, and consist of vegetable impressions, and bivalve shells of marine origin.

The soils of the millstone grit are generally very poor, and are characterised by elevated and heathy moors and peaty swamps; but where shales and limestone occur, the soil is improved.

CARBONIFEROUS OR MOUNTAIN LIMESTONE.

This rock is extensively developed in England; it forms the larger portion of the Mendip range in Somersetshire, surrounds and supports the great

coal deposit of South Wales and the lesser one of the Forest of Dean, underlies the coal measures of North Wales, and occupies a large portion of the counties of Derby, Lancaster, York, Westmoreland, Cumberland, and Northumberland, and pushing its extreme point north at Berwick, generally underlying, and more or less interstratifying with the millstone grit and coal measures. It is the prevailing rock in Ireland, occupying the central, and by far the larger portion of that island, and extending east and west from shore to shore, and with partial interruptions, from Galway Bay on the north-west to Bantry Bay and Cape Clear at its southern extremity; in short, forming the greater part of the surface of all the counties, with the exception of Derry, Antrim, and Wicklow, sweeping round various mountain chains, and filling up every interval and hollow between them. "It supports," says Mr. Weaver, "the coal measures, properly so called, and thus the analogy between the carboniferous series of central and southern England, and that of the corresponding portion of Ireland, is complete; the arenaceous and conglomerate deposits of the old red sandstone in the latter country being surmounted by a sheet of limestone varying in thickness, sometimes attaining a depth of 700 to 800 feet, but generally averaging from 200 to 300, and being in its turn partly covered by coal measures." The prevailing colour of this rock is grey, sometimes whitish grey inclining to yellow, and at others inclined to blue and varying to a rich reddish brown. Some specimens, as those of Kilkenny and Derbyshire, are of a beautiful jet black. It is imperfectly crystalline, and being often loaded with organic

remains, and capable of receiving a good polish, affords those beautiful shelly marbles so much used for chimney-pieces, and would be preferred to foreign marble for such purposes if they were not so abundant and comparatively cheap. The best specimens are so pure as to contain 96 per cent. of carbonate of lime; but by admixture of other matter, vary to magnesian, argillaceous, ferruginous, bituminous, and fetid limestone. It often appears in beds of great thickness without much visible stratification, but generally with a decidedly stratified character, the divisions being marked by thin seams of clay, and sometimes by veins and nodules of chert (flint), and occasionally, as in Derbyshire, by tabular masses and veins of toadstone (a trap-rock), and by beds of shale and sandstone. This rock is very remarkable for the numerous deep fissures, mural precipices, and extensive caverns, which it so frequently presents, which, blending with steep and lofty woods, produce, by this combination of the sublime and beautiful, the most romantic and interesting scenery, which often delights the eye and arrests the foot of the traveller. In many instances the rock appears as if forced asunder by some convulsive action of nature, as at Clifton, near Bristol, where the river Avon flows through a deep defile of lofty precipices on one side, and steep woods and projecting rocks on the other; and the chasm formed in the Mendip hills at Cheddar, where the rocks tower, in naked and awful grandeur, about 800 feet above the road leading to the village. As the caves in this rock generally occur in places which exhibit all the most enchanting features of British scenery, we

cannot resist the inclination to give the reader Mr. Grenough's account of the situation of some of the most remarkable of them; for the mind which is led by a rational curiosity to inquire into the origin and nature of rocks, cannot be insensible to the grandeur of their forms, or the surpassing beauty and loveliness with which their otherwise rugged features are often invested. What geologist would not forget awhile his particular pursuit, when, from some lofty eminence, as the Wynd Cliff on the Wye, he gazes upon an unexpected scene, such as Milton describes in *Paradise*, presenting a various

“ — interchange
Of hill and valley, rivers, woods, and plains;
Now land, now sea, and shores with forest crown'd;
Rocks, dens, and caves?”

In Westmoreland there is a great cavern in the main limestone, at Danel, five miles from Dufton. In Durham, Hutherborne Cave, near Stanhope, in the 70-fathom limestone, runs above a mile under ground. In Yorkshire, Giggleswick Scar, Kingdale; Wethercat Cave, near Ingleton; Tiernham's Mine, and Old Cave Rock, Conistone Moor; Barefoot Wives' Hole, Hardrawkin. In West's Guide to the Lakes, caverns are mentioned by the names of Hartlepot; Sandpot, Donk Cave, on the base of Ingleborough; Gale Kirke Cave on the south-east of Whernside, Greenside Cave, Chatnet Hole, Hardean Scar, near Hawes, in Wensley Dale; Alan, or Alum Pot, near the village of Sibside, Longchurn, Dicher Pot, Halpot Hole, Hunt-pot Hole, Blackside Cave, Sir William's Cave, Atkinson's Chamber, Johnson's Jacket Hole, and

Gaspar Gill. In Lancashire, Dunald Mill Hole, near Killet, eight miles from Lancaster, near the road to Kirby Lonsdale; Yardhouse Cave and Gingling Cave, in Kingsdale, and smaller caverns in Yeadale. In Derbyshire, Bagshaw's Cavern, south-west of Bradwell; Banford Hole, near Eyham; Binding Hole, near Wirksworth; Charles Wark Cavern, near Eyham; Chelmorton Cavern, Creslow Mine Cavern, Cumberland or Rutland Cavern, near Matlock; Devil's Hall, or Foreside Mine, Castleton; Dove-hole Cavern, Dovedale; Drake Mine Cavern, Elden Hole, Golconda, near Hopton; Post's Hole, Bunton; Knowles Mine Cavern, Peak's Hole, Castleton; Merlin's Cave, Orchard Mine Cavern, Reynard's Hall Cave, in Dovedale.

In Staffordshire, Thors House, or Thyrsis Cave, in Wootton Dale. Ribden and Ruder Caves, near Calder, here receive the waters of the Manifold, &c. Ladchurch, between Swithen Ley and Warnford, is 208 yards long and 40 or 50 deep. Hobchurch Cave, near Wilton Mill, with many others.

In Somersetshire, Lochstone Cavern and Banwell Cave, 12 miles north-west of Wookey. There are also caverns in Charterhouse liberty, Mendip, and Green Ore Farm, 4 miles from Wookey, and a cave called the Lamb Cavern, near East Harptre. An extensive cavern has recently been discovered at Cheddar.

Subterranean rivers are frequent all over the limestone districts. Such are the Manifold, which passes beneath the limestone hills about 3 miles south-west of Ecton Mine, in Staffordshire, and after traversing a cavern about 3 miles through the base of the limestone hills 4 miles in length

reappears near Ilam. The Hamps River also breaks out near the same place. The Ribble and the Greta are also underground rivers. Such, also, are Horton Bech and Bransil Bech, at the foot of Penegent, in Yorkshire. The stream which forms the cataract in Speedwell Mine, near Castleton, is according to the inhabitants proved to be the same as that which traverses the Peak Cavern at that place.

The streams forming these subterranean rivers, are absorbed by funnel-shaped hollows on the surface of the limestone, called provincially, swallows and swallet-holes.

The mountain limestone is sometimes called a metalliferous limestone, from the abundance of its metals, and affords the principal supplies of lead, the mines of which are situated in Northumberland, Durham, Cumberland, Yorkshire, Derbyshire, and North Wales. The lead in these mines is a sulphuret of that metal, commonly called galena. This rock also affords carbonate and phosphate of lead, antimoniated lead ore, sulphuret and carbonate of copper, sulphuret, carbonate, and oxide of zinc, iron pyrites, hæmatitic iron ore, and also oxide of iron, carbonate and sulphate of barytes, calcareous spar, fluor spar, (Derbyshire spar,) quartz crystals, (Bristol and Derbyshire diamonds,) with many other mineral substances. According to a report of Mr. John Taylor, the British lead mines produce annually 31,000 tons, of which, 20,000 tons is afforded by the mountain limestone of Durham, Cumberland, Northumberland, Yorkshire, and Derbyshire; about 10,000 in Wales and Scotland, only partially by that rock, and an inconsiderable portion by the older

rocks of Cornwall and Devon. The ores from the latter counties are, however, rich in silver, and those of Beeralston on the Tamar are said to have afforded as much as 80 to 100 ounces per ton, and those from a mine near St. Michael's 30 to 40 ounces per ton.

The organic remains of the mountain limestone are very numerous, and are very distinct from those contained in the less perfect limestones, the lias and oolites above the coal measures, exhibiting a great change in the inhabitants of the sea in which it was deposited, and consist of a variety of univalve and bivalve shells, the vertebræ of fish, sharks' teeth, and fish palates, a peculiar crustaceous fish, called trilobites, with a great abundance of the zoophytic fossils, called coralites and encrinites, the latter of which are sometimes so numerous as to form a considerable part of the rock; these fossil remains are, however, very unequally distributed, in some parts of the rock prevailing very much and in others nearly absent.

The mountain limestone, as its name implies, often presents bold ridges which rise upwards of 1,000 feet above the level of the sea, with a thickness which sometimes exceeds 900 feet, and is often highly inclined. Numerous faults occur from the invasion of trap rocks, which are particularly remarkable in Derbyshire, where the latter are of the kind called toadstone, or amygdaloid. The more elevated portions of this rock afford but a thin soil, which is often encumbered with detached masses, and uninclosed; in lower situations, however, it affords sweet and even good pasture both for sheep and cattle, and useful soils for convertible husbandry, while its defiles

and steep acclivities are generally clothed with rich woods often producing fine timber trees.

Springs seldom occur on the summits and sides of this formation, but the numerous fissures and caverns of the rock often collect the waters and produce subterranean streams and very copious springs at the base of hills. St. Winifred's spring at Holywell, in Flintshire, is a remarkable instance of this, which throws up 84 hogsheads per minute, which in little more than a mile turns eleven mills, of which three are abreast of each other. In the same neighbourhood are two other copious springs issuing from the same rock, one called St. Ormond's and the other St. Mary's Spring. At the bottom of the rugged defile of Cheddar, another of these abundant springs occurs close to the village, the water of which supplies several mills within a short space. The hot-springs of Buxton, Matlock, and Clifton rise through this rock. Though the water which flows from this rock has the appearance of the greatest purity, it contains a large quantity of calcareous matter in solution, which forms the stalagmites and stalactites which cover the floors and sides, and are suspended from the roofs of its numerous caverns. The manufacturers of edge-tools prefer this water for grinding them, from its being less liable to rust them than any other; and the celebrated manufactory of scythes, at Mells, in Somerset, is supplied by this water, to which they are supposed to owe in part their excellent temper.

THE OLD RED SANDSTONE OR DEVONIAN SYSTEM.

The Old Red Sandstone is the next formation in *the descending order* beneath the carboniferous or

mountain limestone just described; it is extensively developed in the West of England, in the counties of Hereford, Worcester, Shropshire, Brecon, and Pembroke, in South Wales, and appears in Somerset, Westmoreland, and Cumberland; it also occupies a considerable portion of Scotland, in detached spaces, from the Orkneys and the Pentland Frith to Northumberland, and continuously from Stonehaven on the north-east coast, to the Clyde in the south-west, besides some parts of the extreme north-west on the coast line of Sutherland. In Ireland, the old red sandstone occurs in the counties of Fermanagh and Monaghan in the north, in Mayo in the west, in several detached portions in the midland counties, and the larger part of Waterford, Cork, and Kerry, in the south and south-west, extending continuously from Waterford east on the harbour, to Dingle and Bantry Bay in the extreme west. In England and Wales this formation admits of division into three principal strata; namely, the old red conglomerate, the cornstone and marl, and lastly, the tilestone, which is the lowest. The uppermost of these strata consists of conglomerates of pebbles of older rocks, but more frequently of hard and fine-ground sandstone, with thin layers of marl; this stone in Herefordshire forms an excellent building-stone, and in some places is quarried for tiles. The conglomerate beds are well exhibited on the banks of the Wye, between Ross and Monmouth, and near Tintern Abbey. The cornstone and marl stratum consists of clayey and marly beds interstratified with sandstone and imperfect limestone; the blended ingredients of these beds afford, by their decomposition, the rich arable soils and fine pasture and

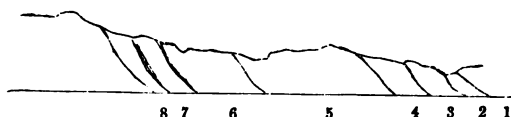
orchard lands, of Hereford and the adjoining counties: the cornstone, which is of very irregular occurrence, appearing at intervals, sometimes as a coarse, imperfect limestone, and at others, of fine grain and more crystalline character, and affording flag-stones. In some parts, as in Caermarthen-shire, the limestones are more developed and thicker, and abound in impressions of fish, the peculiar forms and brilliant lustre of which afford a striking characteristic of this formation. The tilestone, the lowest of these strata, is the least considerable, and is characterised both by its mechanical structure and its fossil remains. It forms a lofty range of fifteen or sixteen hundred feet in Caermarthenshire and Brecknockshire, in which tilestones are extensively quarried. These tilestones consist of finely laminated micaceous sand of a greenish colour, and are blended with red shales producing by their decomposition a red soil. Organic remains are abundant in particular localities.

In Caermarthen and Brecon this formation attains an elevation of more than 2,500 feet above the level of the sea. The uppermost part consists of a conglomerate of white pebbles imbedded in a red matrix. It appears also as a conglomerate in Westmoreland and Cumberland, where it forms lofty hills and is of great thickness.

In Scotland this formation extends in a continuous line of 120 miles, from Stonehaven to Dumbarton, and is many thousand feet thick, and occupies the larger part of Caithness; farther south it occupies a large tract of country on either side the Murray Frith, and on the north-west most of the coast from Cape Wrath to the Isle of Skye,

while smaller deposits of it occur in several of the islands farther south.

In the northern part of Scotland the old red sandstone appears to rest upon the oldest sedimentary rocks and granite, and the several members of which it is composed may be represented by the following section.



Upper.	1	Quartzose yellow sandstone.
	2	Impure limestone.
	3	Gritty red sandstone.
Middle.	4	Grey fissile sandstone.
	5	Red and variegated sandstone.
Lower.	6	Bituminous schists.
	7	Coarse gritty sandstone.
	8	Great conglomerate.

The stratum No. 8 of the above section consists of a deep conglomerate, which forms a lofty mountain chain, in Caithness, the highest part of which is the Morriston Hill, which has an elevation of 3,500 feet above the level of the sea, and which is entirely composed of the lower beds of this formation. On this conglomerate rests a coarse sandstone, occasionally containing pebbles of a red or yellow colour, alternately with green and red marls. The difference between this and the underlying rock appears to consist chiefly in the state of mechanical division of their materials. Upon these sand rocks rest a great thickness of strata, composed of calcareous and bituminous schists containing mica, which afford valuable paving-stones, and

are extensively employed for that purpose. These beds of schist abound in the organic remains of fish, with some traces of vegetable impressions. The same rock occurs in the Orkney Islands, and corresponds with that extending from Cromarty to Bamffshire. The upper strata consists of soft red sandstones and marls, which appear on the precipice of Dunnet Head, on the north, and correspond with those on the south of the Grampian Hills. The middle group is developed in Forfarshire and Moray, and consist chiefly of rocks of a bluish grey colour, and sometimes forming hard flag-stones used for paving. The beds of the upper part of this formation are composed of red conglomerate and variegated sandstone, alternating with limestone, and occasionally covered with thick beds of yellow sandstone. This upper portion occupies extensive areas and is rich in fossil remains.

Until within the last few years, the stratified rocks which compose the greater part of Devon and Cornwall, and the western extent of Somerset, from their mechanical structure and slaty character, were classed under the general term of greywacke or slate rocks, and the limestones which appear both on the north and south were called transition limestones, and were considered to be of much greater antiquity than the old red sandstone above described; but recent investigations by Professor Sedgwick, Sir R. Murchison, and Sir H. T. De la Beche, have shown that besides a mass of granite, the central part of Devon is occupied by sands and shales containing culm, corresponding with the coal measures, and that the slaty and limestone rocks of the north and south of Devon,

and the slates of the north and south of Cornwall, though differing widely in their mechanical structure from the old red sandstone, contain the same organic remains, and are therefore now considered to be of contemporaneous origin. This discovery has led to the general adoption by Geologists, of a new classification of these rocks under the general term of the Devonian System, though for convenience and from the difference of structure they are still spoken of separately.

The propriety of the adoption of this new term must be evident, because, though the Devonian rocks exhibit the same fossils as the old red sandstone, it would be an abuse of terms to call them by that name, but both might conveniently, or with less impropriety at least, be arranged under the general term Devonian. There was also a necessity for this new arrangement in order to preserve the true order of the stratified rocks in point of age, and to prevent the so-called greywacke rocks and slates of Somerset, Cornwall, and Devon from being confused with older rocks—those of Wales, for instance—to which that term is yet generally applied. The following is a section across Devonshire, which will afford some idea of



the relative position of the culm beds, slate and limestone, the rocks called Devonian, and the central mass of granite upon which they repose and which appears to have upheaved them.

Here the culm beds are seen to repose upon the Devonian rocks on one side, and the central mass of granite on the other, and may be considered to represent the carboniferous system in this part of the island. Beneath this, and on either side of the granite, appear the Devonian rocks, consisting of an extensive series of greywacke slate interstratified with limestone containing fossil remains. The junction and alternation of the limestone with the slate are well exhibited in the face of rock at the Laira Bridge, near Plymouth, where the junction of the great mass of limestone of Plymouth Sound, of which the breakwater was formed, unites with the more prevailing rock of slate in that part of Devonshire. Here the fragments detached from the rock often exhibit slate on one face and limestone on the other. A portion of this rock is black traversed with beautiful white veins, and, being capable of receiving a high polish, is worked for ornamental purposes as a secondary marble. The slate rocks of this neighbourhood and on the banks of the Tamar, above Plymouth, are of a blue colour, and afford good roofing slate, and thick slabs which are used for the construction of water-cisterns, paving and tomb stones, and other purposes. The quarries of Delabole, in the north of Cornwall, also afford slates of excellent quality. Both in the south of Devon and Cornwall the colour of this so-called greywacke slate is deep red, and easily separating in thick layers, affords a convenient and durable stone for building purposes.

The slate in the north and west of Cornwall, called *killas* by the miners, is much paler; and when separated, the laminæ here for the most part have a

shining surface. In this rock and the granite upon which it rests are situated the principal part of the tin, copper, lead, and manganese mines. The tin mines are said to be richest at the juncture of the granite and slate, as in the neighbourhood of Redruth.

In the south of Devon this formation affords a red soil, which with the application of lime, which is universally used, is tolerably productive, and in some situations affords good pasture and even thriving orchards, as may be seen in the lovely valley of the Dart, where the blended features of meadows, orchards, hilly crofts and woods, present scenes of surpassing richness and beauty. In the north the agricultural aspect of this formation is less favourable, and, partly owing to the greater elevation of the country, the soil is less productive. On the shore of the Bristol Channel the rocks rise from 1,200 to 1,500 feet above the level of the sea, and with the deep ravines which descend through it present scenes of the most awful grandeur, while the richness and picturesque beauty of the Tamer and the Torridge, with the advantage of greater boldness, are scarcely inferior to that of the Dart.

The slaty soils of Cornwall, especially in the mining districts, are generally poor and meagre, and in a colder climate and less favoured by rain would be very sterile; as it is, large portions of the country remain unenclosed, with a scanty covering of heath and poor grass, affording only a scanty subsistence for the few goats which are kept to supply milk. The cultivated lands, however, are rendered tolerably productive by the calcareous sea-sand which on several parts of the

northern coast is washed up upon the beach; this sand, rich in sea-salts, is carried many miles into the interior, and extensively used as a fertilizing dressing for the land. The defects of the soil and the deficiency of the agricultural produce of the slates of Cornwall are largely compensated by their mineral treasures.

CHAPTER XI.

The Silurian System—Order of Super-position—Llandeilo Flags—Caradoc Sandstone—Wenlock Shale—Lower Ludlow Shale—Ludlow Limestone—Upper Ludlow Shale—Organic Remains—Foreign Localities—Agricultural character.—The Cambrian, Cumbrian, or Schistose System—Structure of the Rocks—Roofing Slates—Great thickness—Organic Remains—Cleavage.—Stratified, Primary, or Non-fossiliferous Rocks—Clay Slate—Structure—Localities—Bangor Slate-quarries—Changes effected by Trap Rocks.—Chlorite Slate—Quartz Rock—Structure—Localities.—Hornblende Rock and Slate—Chemical and Mineral character.—Primitive or Crystalline Marble—Carrara Marble—Origin of—Metamorphic Marble of Antrim and the Isle of Skye.

THE SILURIAN SYSTEM.

THIS series of rocks are so named from their occupying principally that portion of the borders of England and of Wales inhabited in ancient times by a people called the Silures. They are the next in the descending order to the old red sandstone, and have been separated into two principal divisions consisting of different strata, in the following manner (ascending):—



- | | | |
|-----------------------------|-----------|-----------------|
| 1. Llandeilo flags . . . } | | Lower Silurian. |
| 2. Caradoc sandstone . . } | | |
| 3. Wenlock shale . . . } | | |
| 4. Wenlock limestone . . } | | |
| 5. Lower Ludlow shale . . } | | |
| 6. Ludlow limestone . . } | | |
| 7. Upper Ludlow shale . } | | |
- | | |
|---|-----------------|
| } | Wenlock Series. |
| } | Ludlow Series. |

}	Upper Silurian.
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The Llandeilo flags rest upon the older Cambrian rocks, and consist of hard, dark coloured sandy beds, partly calcareous, which appear near the town of Llandeilo, in Caermarthenshire. Resting upon these flag-stones there occurs an extensive range of sandstones, containing fossils with calcareous layers called the Caradoc sandstone, which compose the upper part of the lower division of this group. In the lower part of this division there appears a reddish purple sandstone, blended with streaky marks of a green colour. Calcareous bands succeed, alternating with sandy and pebbly gritstones, which afford flag-stones. The calcareous beds contain abundance of fossils, and are burnt for lime. Upon these rests a deep stratum of micaceous sandstone of a green colour, finely laminated and containing fossils. The uppermost beds of Caradoc sandstones are also micaceous, containing beds of impure sandy limestone and shelly layers of sandstone.

The Wenlock shale consists of a deep mass of clayey beds, of white or dark grey colour, containing occasional masses of impure limestone. The Wenlock or Dudley limestone forms a prominent feature of this formation, and is the rock upon which Dudley Castle stands, and also forms the bold height of Wenlock Edge, on the banks of the Severn, at Colebrook Dale.

The Wenlock limestone rests upon the shale, is remarkably full of fossils, and consists of thick beds of limestone associated with beds of an impure clay and shale, which pervade the crevices of the stone. The concretions or masses afford excellent lime, and are extensively quarried for *that* purpose.

The lower Ludlow shale resembles the shales of the Wenlock group, and is seen in the valleys between the Wenlock and Aymestry limestone. The steep hills west of Ludlow exhibit its junction with the underlying Wenlock limestone, where it alternates with stony layers, with corals and concretions of clayey limestone; these concretions are generally formed upon some fossil organic body. The principal portion of the lower Ludlow formation is composed of shales, called locally mud-stones, of which the upper portion becomes slightly calcareous. To these succeed sandy flagstones with layers of soapy clay, (used as fullers' earth,) separating them from the overlying beds of limestone.

The Ludlow or Aymestry limestone is of a bluish grey colour, subcrystalline, and full of fossils. It appears at the village of Aymestry, in beds from one to five feet thick, and forms a vertical cliff, at the village of Downton on the Rock, of above fifty feet in thickness. This limestone passes by almost insensible degrees into the lower beds of the upper Ludlow formation. The upper Ludlow shale, which is the newest rock of the Silurian system, consists for the most part of fine-grained yellowish sandstones, which rest upon the calcareous strata just described. This stratum exhibits a thin bed highly charged with fossils, consisting of scales, fins, jaws, teeth, and coprolites of fishes, together with small shells, and cemented with carbonate of lime, oxide of iron, phosphate of lime, and bitumen; and upon this rest a series of micaceous sandstones, which gradually blend with the old red sandstone above.

Though the above description of the structure of the Silurian rocks may be considered correct with regard to the particular localities mentioned, considerable difference occurs in other parts; indeed a constant character never prevails in the mechanical structure of any series or system of rocks, and the only sure ground of their geological arrangement is the character of their organic remains connected with the order of their superposition. The slaty character of the larger portion of the rocks of Cornwall and Devon, resting as they do on granite, led to an erroneous opinion of their real place in the general series of secondary rocks, from which they were denominated greywacke and clay slate, but the discovery of these fossils being the same as those contained in the old red sandstone proved them to be identical in point of age with the last-mentioned formation, however different in mechanical structure, and led to the classification of both under the name of the Devonian Series, as before stated.

Rocks corresponding with the Silurian strata occur in many parts of the north of Europe, including Belgium and the banks of the Rhine, France, Bohemia, Scandinavia, and Russia, for the knowledge of which we are indebted to the researches of those distinguished geologists, Professor Sedgwick and Sir R. Murchison.

The soils afforded by the Silurian rocks are for the most part cold and poor, but some of good quality are found in Caermarthenshire, perhaps owing to the admixture of carbonate of lime.

THE CAMBRIAN, CUMBRIAN, OR SCHISTOSE SYSTEM.

These rocks occupy portions of the east, south-west, and north-west of Wales, part of Lancashire, and the lake districts of Westmoreland and Cumberland. This formation (or at least the upper beds referred to it in the table at p. 72) is not always distinguishable from the lower Silurian just described, and their relative limits are by no means well defined, as their organic remains are nearly the same. They principally consist of fine-grained hard slates, of various shades of purple, blue or green colour, with beds of conglomerate and a dark limestone, associated with slate, called Bala limestone. The character of the slates is familiarly known from the extensive use of them for roofing, as the principal part of the roofing-slates are the produce of these rocks. These beds of slate are of enormous and unknown thickness, and are the lowest in which fossil organic remains are found, consisting of corals, encrinites, and bivalve shells, very sparingly distributed. They are extensively quarried at Penrhyn, near Bangor, the length of the quarry being 700 yards, breadth 300, and depth from the surface 90. The slate is of a dark blue or purple colour, and is of the best quality for roofing. The rock is penetrated with trap-rocks, which when they occur have had the effect of destroying the fissility of the slate, rendering it flinty and turning the colour to black. These rocks are evidently of mechanical origin, and appear to have undergone the greatest changes of position, as they exhibit not only every degree of elevation, but are

frequently contorted or twisted, as if by lateral pressure when in a soft state. Besides the lines of stratification, these rocks present other planes of division, called the lines of cleavage, which form large angles with the former, and are sometimes at right angles with them, and are the means by which the slates are separated for the purpose of roofing. These planes of cleavage are the more remarkable as they extend in the same direction over extensive districts. This difference between the lines of stratification will be better understood by the following section.



SECTION OF A HIGHLY INCLINED SLATE ROCK.

STRATIFIED, PRIMARY, OR NON-FOSSILIFEROUS
ROCKS.

CLAY SLATE.

This rock, as its name implies, is schistose in character, and contains much argillaceous matter. It is evidently of mechanical origin, and very nearly resembles the greywacke slate above described, though the peculiar minerals it sometimes contains seem to indicate that it has undergone some change from the effects of heat.

It occurs extensively in the lake districts of Cumberland and Westmoreland, in North Wales, Scotland, and Ireland, in all of which places it affords roofing-slates. The lines of cleavage, as in all other slates, meet the lines of stratification at various angles.

Clay slate is sometimes associated with and passes into chlorite slate, talcose slate, and other metamorphic rocks, by gradually acquiring particular minerals which ultimately replace the argillaceous slate.

CHLORITE SLATE.

This rock is frequently associated with clay slate, into which it graduates as well as into mica slate. It is composed of the mineral called chlorite, which sometimes occurs alone, and at others mixed with quartz, felspar, hornblende, &c. in different proportions.

QUARTZ ROCK.

This rock is of frequent occurrence amongst the more ancient strata. It varies in texture from a distinctly granular structure to one in which all, or nearly all, traces of granular form have disappeared; the same rock sometimes exhibiting this diversity of appearance, thereby indicating the different degree of heat by which the originally sandy materials have been affected since their deposition. Quartz rock occurs in Scotland and its isles. It is found in the Cordilleras of the Andes, according to Humboldt, where it is of vast extent and thickness, and also in Brazil; in the latter place it yields gold. Extensive tracts of quartz rock have recently been discovered in California, which is very rich in gold.

HORNBLLENDE ROCK AND SLATE.

This rock appears to have been produced by the partial fusion of shales, or clay slate, at such a

degree of heat as enabled the materials to undergo new arrangements, and to assume a particular mineral character. The texture of this rock is granular and crystalline, consisting of hornblende and felspar. The former is always of a dark green, approaching to black, and the felspar generally grey. The different varieties of this rock occur either compact or schistose; namely, such as in addition to hornblende contain quartz, mica, chlorite, &c.

It passes into chlorite slate, clay slate, and mica slate; and alternates with chlorite slate and with gneiss.

PRIMITIVE OR CRYSTALLINE MARBLE.

This rock was formerly called primitive marble from its frequent association with the older rocks, but a better knowledge of this mineral has rendered that title inappropriate with regard to some marbles, as it is found associated with the upper portion of the secondary rocks, and is the result of the metamorphoses of limestone rocks of that period. The celebrated and beautiful Carrara marble is a remarkable instance of this, and is said to be derived from a stratum of the Oolites. All crystalline marbles, it is now generally admitted, have a similar origin, and are produced by the action of heat upon limestones of various ages, the impure matter either separating from them or running into veins or masses. The opinion that such changes have been effected by heat is not merely conjectural, but rests upon the most remarkable facts. At Antrim, in Ireland, the trap rock has penetrated and passed through a chalk rock, by which the igneous rock *has* caused the chalk to become crystalline for the

space of several feet from the point of immediate contact.* In the Isle of Skye, where a trap rock comes in contact with the lias formation, the stone of the latter is converted into a variegated marble. Similar instances are mentioned by Sir Charles Lyell as occurring in the Alps.

* "In several parts of the county of Antrim, in the North of Ireland, chalk with flint is traversed by basaltic dykes. The chalk is there converted into granular marble near the basalt, the change sometimes extending eight or ten feet from the wall of the dyke, being greatest near the point of contact, and thence gradually descending till it becomes evanescent. The extreme effect, says Dr. Berger, presents a dark brown crystalline limestone, the crystals running in flakes as large as those of coarse primitive limestone; the next state is saccharine, thin, fine grained, and arenaceous; a compact variety, having a porcellaneous aspect, and of a bluish grey colour, succeeds; this towards the outer edge becomes yellowish white, and insensibly graduates into unaltered chalk. The flints in the altered chalk usually assume a grey yellowish colour. All traces of organic remains are effaced in that part of the limestone which is most crystalline."

Calymene.



Trinucleus.



Illænus.



TRILOBITES FROM THE SILURIAN LIMESTONE.

CHAPTER XII.

Mica Slate—Structure and Mineral character—Contains Garnets—Localities and Elevation—Gneiss—Composition and Mineral character—Localities and general distribution—Aspect of the Surface—Sterile character of the Soil of this Rock, and that of the Mica Schist.—Mineral Products.—Unstratified Rocks—General character—Igneous origin—Mineral composition—Trap or Plutonic Rocks—Resemblance of to Lavas—Probable mode of formation—Remarkable experiment upon by Mr. Watt—Igneous Rocks of Scotland and of Sicily—Close connexion between Plutonic, Trap, and Volcanic Rocks—Passage of Granite into Basalt—Variety of, mineral character, and principal constituents—Principal Igneous Rocks.

MICA SLATE.

THIS rock is chiefly composed of mica and quartz dispersed in laminæ, and from the crystalline character of its ingredients presents at once a slaty and metallic appearance. It differs from gneiss in containing no felspar. The layers are often exceedingly contorted or twisted, as if thrown into this form when in a soft or flexible state; it often contains garnets in great abundance, and graduates on the one hand into gneiss, and on the other into talcose or chlorite slate, and other rocks of similar character.

This metamorphic rock occupies a large portion of the surface of Scotland, extending from about Stonehaven in Kincardineshire, on the east, to the Mull of Cantire in the North Channel; and occupying the larger portion of the counties of Forfar, Perth, and Argyle, the islands of Islay and Fern, with portions of Bamffshire and Inverness; comprehending therefore the most elevated and mountainous parts of Great Britain,

of which the following mountains are some of the principal, whose lofty summits and imposing grandeur form so large a portion of the sublime scenery of that part of the kingdom:—the Ben Glœ, Benchocan, Ben Chonzie, Ben Lawers (4,015 feet), Ben Lomond, Ben More, Ben Voirlick, Mont Fourvanny, Mount Balloch, &c. In the North of Ireland the mica slate occupies nearly the whole of Donegal, with part of Londonderry and Tyrone, and on the west the larger part of Mayo and Galway. It is a very prevailing rock in most countries, and forms often a very large portion of the most elevated mountain chains.

GNEISS.

This rock is generally schistose or slaty, with the laminae often exceedingly contorted, and consists of the ordinary crystalline components of granite, quartz, felspar, silica, and hornblende, with a frequent mixture of other minerals. The composition is, however, very variable, seldom preserving a constant character in any locality, and when its fissile arrangement becomes obscure or lost, it so much resembles granite as not to be readily distinguished from some specimens of that rock, more especially when, as sometimes happens, large crystals of felspar, resembling horses' teeth, are distributed through it, as in the celebrated granite of Haytor, in Devonshire. This appearance occurs in the gneiss of the Alps and of Scotland. It must be evident that no system of names can carry any precise idea of the composition of such rocks, which must originally have been so variously compounded, and subsequently so differently modified by *chemical and mechanical agencies*. This rock

occupies by far the larger portion of the central Highlands of Scotland, from the Grampian range inclusive to the northern shores of Sutherland, and from the mouths of the Yethan and the Dee on the east, to the broken shores of Inverness and Rosshire on the west. The western isles are entirely composed of the same rock, as are also those of Tiree, Coll, and the larger part of the Shetland group. This rock, like the mica schist before noticed, occurs abundantly in most parts of the world, forming with it the great mass and steep acclivities of almost all extensive mountainous regions, generally descending beneath all the other stratified rocks, and also rising above them to the greatest elevations. The general aspect of the surface of both the mica schist and gneiss, is that of wildness and sterility, where lofty mountains and wide irreclaimable heaths occupy the largest portion; but at the same time exhibiting in many a deep and fertile glen the most beautiful contrast of abundant corn-fields, rich pastures, and luxuriant woods, with the rugged features and awful sublimity of the surrounding district. This rock produces a great variety of metals. The mines of Bohemia, Saxony, and Salzburg, are situated on it, and afford the ores of tin, lead, copper, silver, and cobalt. In South America the metallic veins of this rock are not found very productive, but in some districts yield small quantities of gold, silver, copper and lead.

UNSTRATIFIED ROCKS.

These rocks form a large part of what is called the crust of the earth, as they underlie and penetrate most of the stratified rocks, from all of which

they differ in exhibiting no appearance of having been deposited by the action of water, in their highly crystalline texture, and in the indications they constantly afford of their subterranean and igneous origin; and they appear to have been the proximate cause of the elevation of mountain chains, and all the great inequalities which the surface of the earth exhibits. Under the general terms of trap and plutonic rocks, but having different names according to their obvious appearance or their mineral composition, as we have before noticed, they are found intruded into, fracturing, and overlying the stratified rocks of all ages, and more or less effecting changes in their condition and mineral character. From their resemblance in mineral composition to the lavas poured forth from volcanic mountains, either at their summits, or on their flanks, or beneath the sea, there is the greatest reason to believe that the different structure they exhibit is principally owing to the pressure under which they were formed, and the time required for their cooling. An experiment of Mr. Gregory Watt on the effect of the rate of cooling of molten basalt threw considerable light on the manner in which mineral substances are affected by similar operations on the grand scale of nature.

This philosopher fused seven hundredweight of an amorphous basalt, named Rowley Rag, described as fine-grained, and of a confused crystalline texture. The fire was maintained for more than six hours, and the fused mass was suffered to cool very gradually, so that eight days elapsed before it was removed from the furnace. The mass was then three and a half feet long, two feet and

a half wide, about four inches thick at one end, and about eighteen inches at the other. The irregularity of form resulting from the shape of the furnace was highly advantageous, showing the arrangement of bodies passing from a vitreous to a stony state. A portion taken out while the basalt was in fusion became perfect glass. The most important result observed was the formation of spheroids, sometimes extending to a diameter of two inches. They were radiated with distinct fibres, the latter also forming concentric coats where circumstances were only favourable to such arrangement. But this structure gradually disappeared when the temperature was sufficiently continued, the centres of most of the spheroids becoming compact before they attained the diameter of half-an-inch. This structure gradually pervades the whole body of the spheroids. A continuation of the temperature favourable to arrangement speedily induces another change. The texture of the mass becomes more granular, its colour rather more grey, and the brilliant points larger and more numerous; nor is it long before these brilliant molecules arrange themselves in regular forms, and finally the whole mass becomes pervaded by thin crystalline laminæ, which intersect it in every direction, and form projecting crystals in the cavities. By this experiment it appears that the same mineral compound which by rapid cooling produces a glassy substance, by a slower rate undergoes changes by which the same matter is formed into granular crystals. Treating of the same subject Dr. Macculloch, after examining with great attention the igneous rocks of Scotland, observes, "that it is a mere dispute

about terms to refuse to the ancient eruptions of trap the name of submarine volcanoes, for they are such in every essential point, although they no longer eject fire and smoke." The same author also considers it not improbable that some of the volcanic rocks of the same country may have been poured out in the open air. Sir Charles Lyell, in his admirable work on the principles of geology, states that "the recent examination of the igneous rocks of Sicily, especially those of the Valdi Noto, has proved that all the more ordinary varieties of European trap have been produced under the waters of the sea in the new Pleiocene period, that is to say, since the Mediterranean has been inhabited by a great proportion of the existing species of shell-fish. We are therefore entitled to expect that if we could obtain access to the existing bed of the ocean, and explore the igneous rocks poured out within the last 5,000 years beneath the pressure of a sea of considerable depth, we should behold formations of modern date, very similar to the most ancient trap rocks of our island. We cannot, however, expect the identity to be perfect, for time is ever working some alterations in the composition of these masses, as, for example, in converting porous lava into amygdaloids (toadstone)."

—*Passage of Trap into Granite.*

"If a division be attempted between trappean and volcanic rocks, it must be made between different parts of the same volcano,—nay, even the same rock which would be called "trap" when it fills a fissure and has assumed a solid crystalline form, from slow cooling, must be termed volcanic or lava when it issues on the flanks of the mountain."

"Some geologists may, perhaps, be of opinion

that melted matter which has been poured out in the open air, may be conveniently called volcanic; while that which appears to have cooled at the bottom of the sea, or under pressure, but at no great depth from the surface, may be termed trap; but it is very doubtful whether such distinctions can be made without confusion, and whether we shall not be obliged to consider trap and volcanic synonymous terms. On the other hand, the difficulty of distinguishing the volcanic from the plutonic rocks is sufficiently great, there being an insensible passage from the most common forms of granite into trap or lava."

"The ordinary granite of Aberdeenshire," says Dr. Macculloch, "is the usual tertiary compound of quartz, felspar, and mica; but sometimes hornblende is substituted for the mica. But in many places a variety occurs, which is composed simply of felspar and hornblende; and in examining more minutely this duplicated compound, it is observed in some places to assume a fine grain, and to become undistinguishable from the greenstones of the trap family. It also passes in the same uninterrupted manner into basalt, and at length into a soft claystone with a schistose tendency on exposure, in no respect differing from the trap Islands of the western coast." "The same author," continues Sir Charles Lyell, "says that in Shetland, a granite composed of hornblende, mica, felspar, and quartz, graduates in an equally perfect manner into basalt."

It will appear from the above extracts that the external appearance of these unstratified rocks is exceedingly various, and that the variety they present has been very much influenced by the

circumstances under which they have been produced. They are all principally composed of greater or less proportions of the following chemical substances, the aggregate quantity of each of which may be considered as indicated by the order in which they are mentioned, beginning with the greatest; viz. silica, alumina, lime, magnesia, oxide of iron, potash, soda, oxide of manganese. These, however, exist in the form of minerals which are distinguished by the following terms:—Quartz (pure silex), felspar, mica, hornblende, and augite, of which some explanation will be given hereafter.

The following are the principal rocks of igneous origin, including those called trap and volcanic:—Granite, porphyry, basalt, toadstone or amygdaloid, greenstone, serpentine, compact felspar, wacke, claystone, clinkstone, melaphyre, trachyte, pitchstone, augite rock, hypersthene, cornean, trap tuff, lava, obsidian, pumice, volcanic conglomerate. An explanation of the composition or nature of these will be found in the form of a Glossary, which will contain also an explanation of terms used in geology, and other miscellaneous relative information.

CHAPTER XIII.

Connexion of Chemistry and Mineralogy with Geology—Elementary substances—Laws by which they are governed—Chemical affinity—Electric affinity—Equivalents, or combining proportions—Decomposition of compound bodies—Chemical changes of mineral substances—Chemical agency of Electricity—Wonderful results of chemical action.—Gaseous elements—Oxygen—Hydrogen—Carbon—Nitrogen, or Azote—The Atmosphere—Chlorine—Sulphur—Phosphorus—Lime—Magnesia.

The beginner, who has been led to investigate the interesting phenomena of geology, and has heard the various names given to the substances of which the crust of the earth is composed, will naturally feel desirous of knowing something more of their nature; that is, of the elements, or *primary* forms of matter which enter into their composition, and the laws by which their combinations are regulated; in other words, the chemical properties of matter. It will be the object of the few following pages to attempt to impart such a degree of knowledge as may enable those who have not previously turned their attention to chemistry, to form at least such correct general views of the subject, as may suffice for the intended purpose. Both chemistry and mineralogy are intimately connected with the science of geology; but the limits of an elementary work like the present will not allow us to say more upon the former subject than is indispensable for the right understanding of the leading features of the latter; and we must therefore refer the reader who wishes for more particular and extended information on those very interesting relative departments of knowledge, to works expressly devoted to them.

The total number of elements, or primary forms of matter, of which all known substances are compounds, is 54, and are the following; to each of which is added its equivalent number, or combining proportion:—

	Equivalents.		Equivalents.
Aluminum . . .	13	Mercury . . .	200
Antimony . . .	44	Molybdenum . . .	48
Arsenic . . .	38	Nickel . . .	30
Barium . . .	69	Nitrogen . . .	14
Bismuth . . .	71	Osmium . . .	100
Boron . . .	11	Oxygen . . .	8
Bromine . . .	78	Palladium . . .	53
Cadmium . . .	56	Phosphorus . . .	12
Calcium . . .	20	Platinum . . .	98
Carbon . . .	6	Potassium . . .	40
Cerium . . .	50	Rhodium . . .	52
Chlorine . . .	36	Selenium . . .	40
Chromium . . .	28	Silicon . . .	8
Cobalt . . .	30	Silver . . .	110
Columbium . . .	185	Sodium . . .	24
Copper . . .	32	Strontium . . .	44
Fluorine . . .	18	Sulphur . . .	16
Glucinum . . .	18	Tellurium . . .	64
Gold . . .	199	Thorium . . .	60
Hydrogen . . .	1	Tin . . .	58
Iodine . . .	126	Titanium . . .	24
Iridium . . .	98	Tungsten . . .	94
Iron . . .	28	Vanadium . . .	68
Lead . . .	104	Uranium . . .	208
Lithium . . .	6	Yttrium . . .	32
Magnesium . . .	12	Zinc . . .	33
Manganese . . .	28	Zirconium . . .	33

Beside the general law of gravitation, by which all matter is attracted to one common centre, and which acts at the greatest distances, and that of corpuscular attraction, which acts only at insensible distances, these elements, or primary atoms of matter, are subject to a peculiar law, called chemical attraction; by which one atom attracts another, and forms what is called a chemical union *with it*. This tendency of one element to unite

with another is called chemical affinity : and the union itself is chemical combination. Each individual element, however, manifests this tendency to unite with others in very different degrees ; and this partiality or preference of one for another is called elective affinity.

In these chemical unions of the elements, to form compounds, they unite in exact and known proportions, by weight, and in no other. For instance, if one pound of the gaseous element called hydrogen be mixed with eight pounds of another gaseous element called oxygen, and fire be applied to the mixture, these gases instantly unite with violence, giving out flame or heat and light, and form nine pounds of the neutral compound—water ; but if there had been more than one pound of hydrogen, or on the other hand, more than eight pounds of oxygen, the excess in either case would have remained unchanged, and only the same quantity of water would have been produced.

The compound is called neutral because it resembles neither of the elements of which it is composed. The number expressing the weight of the combining proportion of each element is called its *equivalent*, or *combining proportion* ; thus the equivalent of hydrogen is 1, and that of oxygen 8. Water, the neutral compound formed of these elements, has also its equivalent number, which is the sum of its two elements, 9. In numerous instances, one, two or more equivalents of one element, will unite with one, two, or more equivalents of another element, producing compounds of very different properties from one another. Thus the equivalent number of carbon (charcoal) is 6 ; and if 6 pounds of that substance be burnt in 8 pounds or one equivalent of oxygen gas, the

result will be 14 pounds of carbonic oxide; but if 16 pounds, or two equivalents, be used, the resulting compound will be 22 pounds of carbonic acid. It must be evident from what has been stated before, that the equivalent number of carbonic oxide must be 14, and that of carbonic acid 22; and in these proportions they unite with other substances. We must here observe that it matters not whether we use pounds or grains in illustration of the doctrine of equivalents, as they are mere terms of *proportion*, and not of absolute quantity. The term atom is often indifferently used for equivalent, whether it be a simple element or a compound of many; thus water and carbonic acid are called compound atoms, or equivalents. When it is considered that in numerous chemical combinations a great number of equivalents of one element unite with varying numbers of equivalents of other elements, in each instance producing compounds of very different properties, it may easily be conceived that the products of a few simple elements may be almost infinite. If 28 grains, or one equivalent of lime, which is a compound, as will be hereafter shown, be dissolved in water, and the solution be agitated in a jar with 22 grains, or one equivalent, of carbonic acid, they will unite in a solid state; the lime will lose its burning or caustic property, and fall to the bottom of the jar as an insoluble compound, called *carbonate of lime*; thus showing that compound atoms unite in the proportion of their equivalent numbers, in the same manner as elements. In the latter case, the equivalent number of carbonate of lime is 50.

We have mentioned the elective attraction, or affinity of elements, by which each has a tendency

to unite with some other element in preference to the rest. The same law prevails in their compounds. If the carbonate of lime above mentioned be separated from the water, and a strong acid—vitriolic acid, for instance—be poured upon it, the lime will elect the sulphuric acid, by reason of its stronger affinity for it than for the carbonic acid; the latter, being abandoned, will escape in its former shape of a gas, causing a strong effervescence. Innumerable instances of this so-called elective affinity are in constant action in the chemistry of nature. The various elements which compose vegetable and animal substances have their affinities controlled during life by that mysterious power called the vital principle, which causes them to combine under different arrangements than those they would otherwise assume. When, however, this power ceases—that is, when the plant or animal dies—the elements assert their proper actions; each unites with that for which it has the strongest affinity, new combinations are formed, and an entire destruction of the organic structure ensues. Decay, putrefaction, and fermentation, are such instances, in which the elements resolve themselves by their *elective* affinities into more simple and permanent compounds. Mineral substances undergo similar mutations under the influence of high degrees of heat, which allow of the free action of their elements to assume new arrangements, as in the case of igneous rocks effecting the metamorphoses of others with which they come in contact; namely, the conversion of common limestone and chalk into crystalline marble, that of sandstone into quartz rock, and of shales and slates into hornblende and mica schist, &c. We may also

mention the action of water in dissolving minerals and promoting their mutual decomposition; as in the production of iron pyrites from sulphate of lime and salts of iron, and the decomposition of rocks aided by the chemical affinity of carbonic acid for the substances of which they are composed, by which their separated parts are enabled to enter into new combinations, and often to assume crystalline forms.

The tendency of elements to unite chemically is considered by chemists to be owing to electric action, that is, that those which readily unite are in opposite states of electricity; the one being an electro-positive, and the other an electro-negative; that is, a metal belongs to the former class, and oxygen, which unites with it, to the latter. So also an oxide of a metal, or, as it is called in chemical language, a base, is an electro-positive, and the acid which combines with it to form a salt is an electro-negative. In some cases an electro-positive assumes the opposite character when in contact with another electro-positive, and thus unites with it. This discovery, however, of the seeming proximate cause of the action of simple and compound atoms upon one another, removes but little of our ignorance: it certainly abates none of our admiration of those still mysterious and wonderful primary laws, which have been impressed by infinite Wisdom and Power upon the universe of matter, and are the agents alike of those awful changes which have affected and continue to affect the framework of our globe, and the production and continual renovation of those various forms of life, loveliness and plenty which adorn and replenish its surface.

We have before stated that there are 54 elements; some recent discoveries have, we believe, increased the number to 56. Many of these, however, are of so rare occurrence and of such unimportant amount, that we shall be content with having recorded their names in the foregoing table, and hereafter taking a brief notice of them in the Glossary, reserving for a more particular description in this place the chemical properties of those elements and earthy and alkaline compounds which are more immediately connected with geology, as composing the great mass of the solid surface of the earth, and the watery and gaseous mantles by which it is surrounded, as well as the various forms of organic life by which it is inhabited.

OXYGEN—EQUIVALENT NUMBER 8.

This element, in a state of gas, constitutes about 21 per cent. of atmospheric air; it is colourless, tasteless, and inodorous, and is somewhat heavier than common air. Its presence in the air is indispensable to the life of both animals and plants, on which account it has been called vital air. When we inhale common air, the oxygen it contains is converted by its union with the carbon and hydrogen of the blood into carbonic acid and water, in which state it is again given out in the act of breathing. The consumption of oxygen in this way in confined apartments is the cause of distress in breathing, and a sense of suffocation. Oxygen combines with all the other elements except fluorine, either in a gaseous, fluid, or solid form. With carbon, as we have seen, it forms carbonic oxide, and carbonic acid; with hydrogen,

the fluid water; and with metals it forms those mineral substances called metallic oxides, of which we have familiar instances in the rust of iron, and red lead; thus, combined with other metals, or metal-like substances, viz. silicon, aluminum, calcium, magnesium, potassium, sodium, &c., it forms about half the solid substance of the crust of the earth. It is an acidifying principle, and enters into the composition of most acids.

Oxygen is the active agent in effecting the decay and decomposition of dead animal and vegetable substances, and their destruction by fire, as such substances will neither decay nor burn, when perfectly excluded from the air, as in the vacuum of an air-pump, or by being buried deep in the ground, or under water. As soon as life ceases in vegetables or animals, at ordinary temperatures, the action of oxygen begins to effect their dissolution, and never ceases until they are completely disorganized, and their elements resolved into new compounds. At higher temperatures, rapid combination of oxygen takes place, accompanied with the evolution of heat and light, of which we have familiar instances in the burning of gas, candles, and coals; in these cases the oxygen of the air enters into combination with the carbon and hydrogen of the combustible matter, forming carbonic acid gas with the former, and the vapour of water with the latter. To this rapid action of oxygen the term combustion has been given. Combustible bodies burn with intense vehemence in pure or undiluted oxygen gas. If a burning stick be plunged into a jar containing pure oxygen, it instantly bursts into a brilliant flame, and burns away with the greatest violence.

a heated wire also instantly takes fire, and is soon consumed, giving out intense heat and light. The affinity of oxygen for metals is very variable; it is with difficulty brought to combine with gold and platinum, while it readily forms oxides with others, such as lead, iron, and manganese. The pellicle formed on the surface of melted lead is an oxide of that metal, which is renewed as fast as it is removed. At low, or the ordinary temperatures of the air, both lead and iron unite with oxygen when moisture is present, but in a perfectly dry atmosphere both remain unchanged. From these metals the oxygen is easily separated by means of fluxes,—that is, by burning them in close vessels with combustible matter, which unites with the oxygen, when the metal resumes its former state, while with some other metals its union is so powerful as to require the most energetic chemical means to overcome it.

HYDROGEN—EQUIVALENT NUMBER 1.

Hydrogen, or inflammable air, as it is often called, is the lightest of all gases, its specific gravity compared with atmospheric air being as 1 to 15. It has a powerful affinity for oxygen, and unites with one atom, eight of that element to form water, as we have before stated, and, in the same proportion with oxygen, forms nearly half the dry inflammable substance of plants, called woody fibre, as well as of starch, sugar, and animal matter. It also in a solid form enters into the composition of animal and vegetable oils and fats, which owe their inflammability to its presence. Hydrogen is the inflammable principle of

mineral coal. When coal is distilled in close vessels, as in gas-retorts, the hydrogen unites with a part of the carbon of the coal, and produces the gas called carburetted hydrogen, with which our streets are lighted, and is the same as the inflammable gas of coal-pits, called fire-damp. Uniting with sulphur and with phosphorus, it forms the poisonous and offensive gases which arise from putrefying animal and vegetable substances. Hydrogen constitutes the volatile element in the aroma of flowers and all volatile oils. Pure hydrogen may be obtained from water by causing the steam to pass through a heated gun-barrel, by which the oxygen of the water is detained, and the hydrogen set free. The reunion of these elements by combustion, produces the most intense degree of heat and light. This is effected in what is called the oxy-hydrogen blowpipe. In combination with oxygen, hydrogen forms a solid union with many mineral substances.

CARBON—EQUIVALENT NUMBER 6.

This is the most abundant element of vegetable and animal substances, as it constitutes about 45 per cent. of dry vegetable matter, and about 55 per cent. of dry flesh. It also forms the principal part of mineral coal. It is very combustible, and readily takes fire at a high temperature. We have shown that one equivalent of carbon 6 unites with one equivalent of oxygen 8, to form carbonic oxide, and with two equivalents of oxygen to form carbonic acid. The latter gas forms the choke-damp of coal-pits, and sometimes of wells, and is the cause of death when charcoal is burnt in

close apartments. It is given off abundantly in the fermentation of wine or beer, and sometimes proves fatal to persons who descend incautiously into beer-vats.

Carbon exists in the atmosphere in the state of carbonic acid gas, of which it constitutes about 1,000 parts by weight, and is the source of all the carbon contained in plants, which obtain it by means of their leaves and roots, but principally the former; it also exists in great abundance in sea-water. It has been shown that one equivalent of carbonic acid 22, unites with one equivalent of lime 28, to form carbonate of lime 50. Now as the equivalent of carbon is 6, fifty pounds of the carbonate of lime, or pure marble, will contain six pounds of carbon, or 12 per cent; a very remarkable chemical ingredient in a purely white stone, or as a constituent of chalk. The most familiar form of carbon is wood-charcoal, in which, however, it is still united with the ashes, or earthy part of the plant: the diamond exhibits it in its purest form, which has been proved, by the most exact chemical experiments, to consist of carbon alone, in a crystalline form. Besides coal and limestone, carbon is found united with many minerals; plumbago, or black lead, is a compound of carbon and iron, of which carbon forms from 90 to 95 per cent. This substance is also called graphite, and is found of great purity at Borrowdale, in Cumberland. Cast-iron always contains a considerable portion of carbon. Iron unites with carbon to form steel, to produce which iron bars and powdered charcoal are placed in alternate layers in an oven, and afterwards kept at a red heat for some days, and perfectly excluded from

the air ; by this process, which is called cementation, the iron gradually combines with from 1.3 to 1.75 per cent. of carbon, its texture is much changed, and its surface blistered ; it is afterwards hammered into bars at a red heat. By this operation it becomes less malleable than iron, but gains in hardness and elasticity. Carbon is a powerful antiseptic. Meat placed in powdered charcoal is preserved a long time from putrefaction and is even recovered from the commencing stage of putrescence by being covered with water containing charcoal.

NITROGEN, OR AZOTE.

This element constitutes about 79 per cent. of the atmosphere, in which it appears to act merely as a dilutor. Its equivalent is 14. It is perfectly tasteless and inodorous, and though not poisonous, is incapable of supporting life and extinguishes flame. By burning phosphorus in a jar of atmospheric air over water, the whole of the oxygen is removed, the resulting phosphoric acid being absorbed by the water. Nitrogen constitutes a portion of all animal substances, and is indispensable to the existence of plants ; it abounds, however, much more in the former than the latter, which is the principal cause of their difference. It is the foundation or radical of nitric acid, as that important acid is formed by the union of 1 atom of nitrogen, with 5 atoms of oxygen, and when united with potash, soda, or lime, forms salts, called respectively, nitrate of potash, nitrate of soda, and nitrate of lime.

This process is continually going on in nature, and both nitrate of potash, (nitre,) and nitrate of

soda, are abundantly formed in the soils of warm countries, and are obtained from them by lixiviation, (washing,) and subsequent crystallization. Nitre is chiefly obtained from India, and nitrate of soda is obtained in great quantities from Peru, where the supply is said to be inexhaustible. Nitre is produced artificially in France by the fermentation of vegetable and animal substances, in contact with potash. The nitre thus formed is afterwards extracted from the mass by lixiviation and evaporation. Though nitrogen unites with oxygen, it is with a very feeble affinity, and when mixed with sulphur and charcoal, on being ignited, the oxygen of the nitre unites with those substances with explosive violence, as in the case of gunpowder, which is a compound of these substances. One atom of nitrogen unites with three atoms of hydrogen to form ammonia; with one atom of oxygen it forms nitrous oxide, with two atoms nitric oxide, with four atoms nitrous acid, and with five atoms nitric acid, as above stated.

THE ATMOSPHERE.

The gaseous matter which surrounds the earth consists principally of two of the gases, oxygen and nitrogen, in the proportion of 21 of the former to 79 of the latter, and is confined to the surface by the force of gravity. It is invisible and colourless, and destitute of either taste or smell, is exceedingly elastic, and is used as the standard of weight of all other gases, being reckoned as 1, or unity. At the temperature of 32° it is 769 times lighter than water. At the level of the sea its mean pressure is 15lbs. upon a

square inch, and it supports a column of mercury of 30 inches, and one of water of 34 feet. It is, however, subject to variations of pressure at the same place, owing to causes not well understood; but from some recent observations upon winds and storms, it seems probable that it is owing to the circular motions called vortices, in the centre of which the pressure would naturally diminish. On ascending mountains it is found that the pressure diminishes, and at 15,000 feet is diminished to about half; this diminution of pressure takes place in a geometrical ratio, for equal spaces of ascent, and is so constant and regular as to be adopted as a ready means of measuring the height of mountains, and the altitude attained by balloons. The entire depth of the atmosphere is not precisely known, but from some observations on the refraction of light, it is supposed to be about 45 miles, at which height it must be exceedingly rare.

The mean temperature of the atmosphere at any given latitude varies with the elevation. It receives no heat from the passage of the sun's rays through it, but derives it from the earth, so that its heat must necessarily be greatest at the surface, and is found to diminish 1° of Fahrenheit for every 352 feet of ascent; and thus in every latitude there must be a point of elevation where it never rises above 32° or the freezing point. Under the equator this point is about 15,000 feet above the level of the sea, diminishing progressively with the increase of latitude; at 55° it is 5,034, and at 85° only 117 feet above the sea.

Though the atmosphere consists chiefly of oxygen and nitrogen in the proportions above

mentioned, it is loaded, so to speak, with other matters; for, besides a variable quantity of the vapour of water, it contains about 1,000th part, by weight, of carbonic acid, a proportion which is found to be nearly constant in all situations, and at every elevation where it has been examined. It also contains ammonia and other gaseous impurities, such as the miasm of marshes, and the products of volcanoes. Strictly speaking, however, carbonic acid and ammonia should not be called impurities, as they are both essential to vegetation, and therefore to the animal existence. Our limits, and the nature of our present subject, prevent us from dwelling longer upon this most interesting fluid, the changes and condition of which exercise so much influence upon our health, and are the constant theme of solicitude and observation.

CHLORINE.

Chlorine, as a constituent of sea and common salt, is a very abundant element in nature; its equivalent number is 36. In its gaseous or uncombined state it is very suffocating and offensive to the lungs, proving very injurious to persons affected with pulmonary complaints. With 1 equivalent of hydrogen it forms muriatic or hydrochloric acid; and common salt, or chloride of sodium, consists of 1 equivalent of this element, and 1 equivalent of sodium, the metallic base of soda. It is immediately destructive to the colouring matter of vegetables, and a preparation of it with lime is now generally used for bleaching cotton and linen fabrics; this preparation is called *bleaching powder*. It is also the efficient prin-

ciple in the liquid chloride of lime, so much used for disinfecting foul air and infectious miasms of the apartments of the sick. Its operation in this respect is very interesting. Hydrogen and ammonia are the gaseous components and vehicles of miasms. Now chlorine has a strong affinity for the former, and, uniting with it, forms muriatic acid; which acid, combining with the ammonia, destroys its volatility, and thus the miasm is decomposed. And, further, the lime of the liquid chloride attracts carbonic acid, another injurious gas in close apartments. Chlorine combines with metals and other substances forming those compounds called chlorides; with five atoms of oxygen it forms chloric acid, which combined with potash produces chlorate of potash, a salt extensively used for making lucifer matches.

SULPHUR.

This combustible element is too well known to need description; its equivalent number is 16. It is found in a mineral state in volcanic countries, and the principal supplies for the consumption of Europe are obtained from Naples. It commonly occurs in a massive state, but sometimes is met with crystallized. It also exists abundantly in combination with metals, such as silver, copper, antimony, lead, and iron, forming combinations called sulphurets. Its combination with iron is called iron pyrites (sulphuret of iron), from which it is obtained by exposing it to a red heat in close vessels. Its specific gravity is 1.99, water being 1. It fuses and melts at 232, and at somewhat a higher degree acquires fluidity.

When liquid, it is poured into moulds, and forms the roll sulphur of commerce. In cooling it has a tendency to crystallize, which may be observed by breaking one of these rolls. At a high degree it rises in vapour, and condenses again in close vessels, forming what are called flowers of sulphur. In the open air it burns at the temperature of 300° Fahr., in which case it unites with two atoms of oxygen, and produces sulphurous acid. If burnt in close vessels with nitrate of soda, with the presence of water, it unites with three atoms of oxygen, and forms sulphuric acid, the acid of commerce. Both these acids unite with metallic oxides and form salts; those resulting from the combination of sulphurous acid are called sulphites, and those afforded by sulphuric acid are denominated sulphates. Green copperas is a sulphate of oxide of iron; Glauber salt, a sulphate of soda; and gypsum, a sulphate of lime. The beautiful pigment ultra-marine is a compound of sulphur, soda, and oxide of iron; the natural mineral was exceedingly costly, but it is now made artificially and sold at a comparatively low price. Coals often contain sulphur in the form of sulphuret of iron, which is seen adhering to the fractured surface in thin laminæ resembling gold. It is owing to the decomposition of this mineral, when coals are stowed away in a wet state in the holds of ships, that spontaneous combustion takes place and the consequent destruction of the vessel. Sulphur may be considered as a mineral very generally diffused in the mineral kingdom, in combination with metals from which it is difficult entirely to separate it, which is the more needful as *its* presence is injurious to their malleability. For

this purpose, previous to smelting, iron ores are calcined.

PHOSPHORUS.

This is a highly inflammable substance, which when pure is transparent and almost colourless, and when cut with a knife has a waxy lustre. Its specific gravity is 1.77. At common temperatures it undergoes slow combustion, and is luminous in the dark, and gradually consumes. At the temperature of 150° it fuses, and is converted into vapours at 550° ; its equivalent is 31, and it unites with oxygen in various proportions. Two equivalents combine with five equivalents of oxygen to form phosphoric acid, in which state it is found mineralized with several metals, and with lime forms the mineral substance called apatite or phosphate of lime; with lime and magnesia it forms bone-earth, the residue left when bones are calcined. Phosphate of lime is essential to the growth of plants and the formation of their seeds, and phosphorus is contained in all animal substances. Phosphorus in the shape of phosphate of lime is extensively diffused, as it exists in almost all mineral waters, but is seldom found in any considerable masses.

SILICA.

This earth, commonly called quartz or flint, is composed of one equivalent of an element called silicium or silicon 8, and one equivalent of oxygen 8. It is, perhaps, the most abundant substance in nature, as it is the chief ingredient in all the older rocks and great mountain masses of the

world, and in some instances forms their entire bulk; sea-sand almost entirely consists of it, and it composes, in a more or less finely divided state, more than three-fourths of all fertile soils.

We have a pure specimen of silica in rock crystal; and the glasses of the best spectacles are formed from pebbles of the same substance. From the tendency of silica to unite with alkalies by fusion, and even in a state of minute division when the alkali is dissolved in water, it has been ranked among the acids, and called silicic acid, and such combinations, silicates. It is likewise soluble in water containing carbonic acid, by the action of which, as well as of potash, it is thus rendered capable of being taken up by the roots of plants. Most mineral waters contain silica in solution, and the hot springs of Iceland deposit it in large quantities upon their margins. It forms the principal part of a great variety of mineral substances, and the ores of metals. Fused in certain proportions with soda or potash, it forms glass; and united with alumina, it constitutes the larger portion of porcelain, and all potters' clays and brick-earth.

ALUMINA.

This substance is the plastic principle of all clays, and, next to silica, is the most abundant earth in nature, as it enters largely into the composition of most of the strata, as well as the older and igneous rocks. Pure alumina has such a powerful affinity for water, that it retains half its weight of water at the temperature of 60° Fahrenheit. Though alumina is never found in a state of absolute purity in nature, those beautiful gems,

the ruby and the sapphire, consist almost entirely of it, in a crystalline form. It forms the principal base of the well-known salt called alum, from a solution of which it may be separated in a pure state by an alkali which causes it to precipitate. Alumina is the ductile ingredient of potters' clay, and it forms an indispensable part of all fertile soils, as the means of retaining water and the other fertilizing substances they require. Alumina consists of a metallic element called aluminum, or aluminium, and oxygen; but some doubt exists as to its combining proportion, or equivalent number. Dr. Henry states it to be 10, but according to the late Dr. Turner, it is 13.5; and 2 equivalents of aluminum unite with 3 of oxygen to form alumina.

LIME.

This caustic substance is composed of a base called calcium, whose equivalent is 20, and one equivalent of oxygen 8; its equivalent number is therefore 28. United with one equivalent of carbonic acid 22, it forms carbonate of lime or limestone, of which the purest specimens are calcareous spar and statuary marble. With greater or less degrees of impurity, it constitutes extensive rocks in every part of the world, but is most prevalent, as we have seen, in the newer portion of the secondary strata, or, to speak more precisely, from the old red sandstone, or Devonian system, upwards. The rocks of the latter system, the mountain limestone, and the vast mass of the chalk formation, are almost pure carbonate of lime, while the lias, the oolites, and the limestone of the tertiary strata are more or less mingled with sandy and clayey impurities. All the coral rocks

now in the course of formation are likewise composed of the same substance. The highly crystalline limestones or marbles are metamorphic rocks, which have assumed their crystalline form from the action of heat, of which some striking proofs have been already stated. Besides the great masses of lime above mentioned, lime is extensively diffused, and is chemically combined in various proportions with the materials of many of the oldest stratified, and unstratified, or igneous rocks. When the purest limestone is burnt in kilns mingled with coals or other fuel, its carbonic acid is expelled in the form of gas, by which it loses 44 per cent. of its weight, and impure limestones, of course, lose less in proportion to the quantity of other matter they contain. Quicklime has a strong affinity for water, and when exposed, even under cover, attracts it from the atmosphere, and crumbles down, forming what is called slacked lime, and by the chemists hydrate of lime. It is then a perfectly dry powder, although it contains nine parts in thirty-seven of water. In other words, one equivalent of quick lime 28, unites with one equivalent of water 9, to form hydrate of lime. By a still further exposure and for a longer period of time, the lime attracts carbonic acid from the atmosphere, which displaces the water, and renders the lime again mild, thus restoring it to its original condition as a carbonate of lime. Lime is the most efficient ingredient in mortar and architectural cements. When mixed with sand and water, in process of time, it consolidates and forms a hard stony mass, which is owing to two causes, the union of carbonic acid with the lime, and a combination of

a portion of the latter with silica. So that the hard dry mortar of old buildings, which has often more cohesion than the stone or bricks, consists of a mixture of carbonate and silicate of lime. Lime unites with both mineral and other acids to form salts: thus with sulphuric acid it forms sulphate of lime; with nitric acid, nitrate of lime; with phosphoric acid, phosphate of lime, or bone-earth; with acetic acid (vinegar) it forms acetate of lime, &c. From its powerful affinity for water, and the elements of carbonic acid, it is a powerful destroyer or decomposer of organic substances.

MAGNESIA.

This is a caustic earth, which, like lime and other earths, when pure is perfectly white. It is composed of one equivalent of a malleable metal called magnesium, whose combining number is 12, and one equivalent of oxygen 8. United with one equivalent of carbonic acid, it forms carbonate of magnesia, in which state it is associated with carbonate of lime in magnesian limestone. It also enters into the composition of various minerals.

POTASH.

This well-known alkali was decomposed by the late Sir H. Davy, and found to consist of a brilliant, light, and highly inflammable metal called potassium, united with oxygen, for which it has so powerful an affinity, that upon being thrown into water, the latter is instantly decomposed with intense light and heat. The equivalent number of potassium is 40, and it unites with one equivalent of oxygen 8, to form potash.

Potash is a constant ingredient of the mineral called felspar, of which it generally forms about 14 per cent.; it therefore constitutes a part of many of the older rocks, but more particularly of granite. It is a necessary ingredient of all fertile soils, and is found in the ashes of almost all plants, from which it is separated by lixiviation for the purposes of the arts, in which it is principally employed in the manufacture of soap and glass, and by the chemists is used as a flux. Potash has a powerful affinity for most acids, with which it forms salts; and its attraction for water is so intense, that it retains a considerable portion at a white heat. It is found in a great variety of minerals. The potash of commerce is combined with carbonic acid, and is called carbonate of potash. By the chemists the pure alkali is called *potassa*.

SODA.

This alkali is also an ingredient of some of the igneous and older rocks, and forms from 10 to 14 per cent. of that called compact felspar, and is also found in many other mineral substances. As it is the basis of common salt, it is one of the most abundant substances in nature, forming not only the principal part of sea-salt, but also that of extensive rocks beneath the surface of the earth, and even, in many places, considerable hilly ranges. Soda consists of 1 atom of a soft and shining metal called sodium, whose equivalent number is 24 united with 1 atom of oxygen 8. Chemistry is indebted to Sir H. Davy for the decomposition of this substance also, as well as that of all the earths previously mentioned. Until lately, common salt was considered to be a combination of muriatic

acid with soda, but it is in reality a chloride of sodium, as before stated under the head of chlorine; and it is only when dissolved in water that it becomes, by the decomposition of the latter, a muriate of soda. This substance is much more extensively used in the manufacture both of glass and soap than potash, for which purposes it was formerly obtained from the ashes of the salsola and kelp, but is now produced in vast quantities, and at much less expense, by decomposing common salt, which is effected in large manufactories. Soda, like potash, forms with acids a great variety of salts, of which Glauber salts (sulphate of soda) is a familiar instance. It is an essential ingredient in all fertile soils, and is always found in the ashes of plants. The soda of the shops is a carbonate, united with a large portion of water.

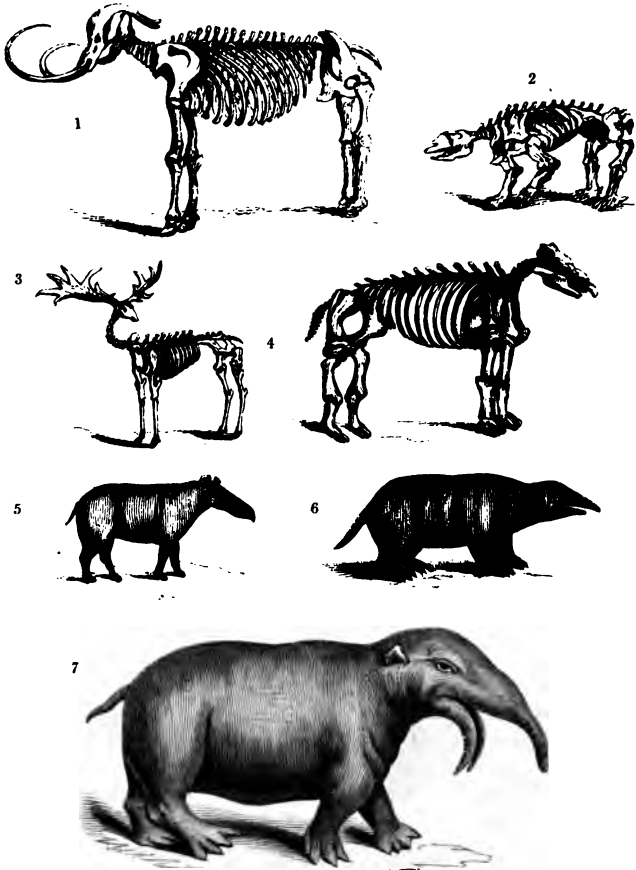
IRON.

This metal is of almost universal prevalence, as it is found in a mineral state in every part of the world. In many countries, vast mountain masses are entirely formed of its ores, in which it exists as an oxide, that is, united with oxygen, though of various degrees of purity. The purest kind is called magnetic iron ore, from which the superior Swedish iron is produced. The greater part of the iron produced in England is obtained from the clay ironstone of the coal measures, in which the metal is mineralized with carbon, sulphur, silica, and alumina, from which it is separated by fluxing the ore in furnaces with lime and coal.

The equivalent number of iron is 28, and it unites with 1 equivalent of oxygen to form the black oxide, and 3 equivalents of oxygen unite

with 2 of iron to form the red oxide, in this state it forms the colouring matter of almost all soils and rock, most of which without its presence would be entirely white. In its oxidised state it exists in all plants that serve to sustain animals, and their existence every moment depends on its presence in the blood, in which it serves as a vehicle of oxygen to every part of the animal system. The oxide of iron forms numerous salts, acids, and imparts a variety of beautiful colours to minerals. Iron is at once the most generally diffused, and the most truly valuable of all metals.

1. *Elephas antiquus*, or Mammoth, found abundantly in the gravels and other places.
2. *Megatherium* found in the river Luxan, near Buenos Ayres, America.
3. *Cervus giganteus*, from the bogs of Ireland.
4. *Mastodon giganteus*, found in considerable numbers in North America.
5. *Palæotherium magnum*, restored from its bones, found in the beds of Paris, belonging to the Tertiary strata.
6. *Megatherium* restored.
7. *Dinotherium giganteum*, found abundantly in the Miocene or Tertiary Strata, at Eppelsheim, Hesse Darmstadt.

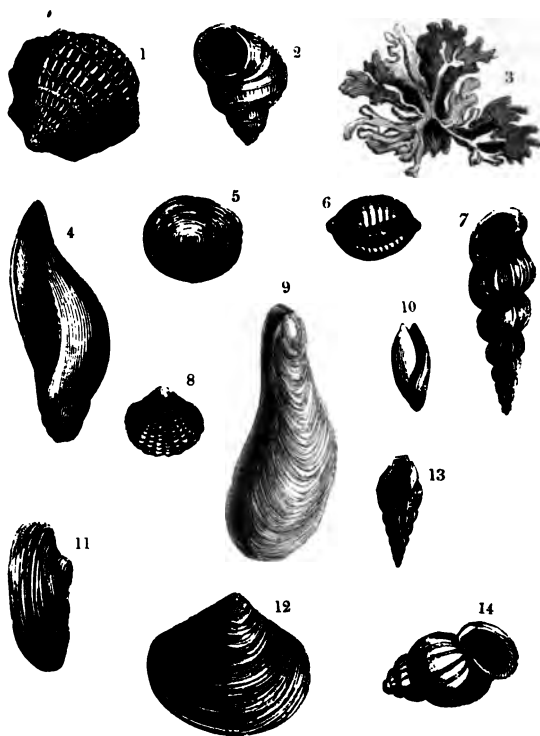


Scale of feet.



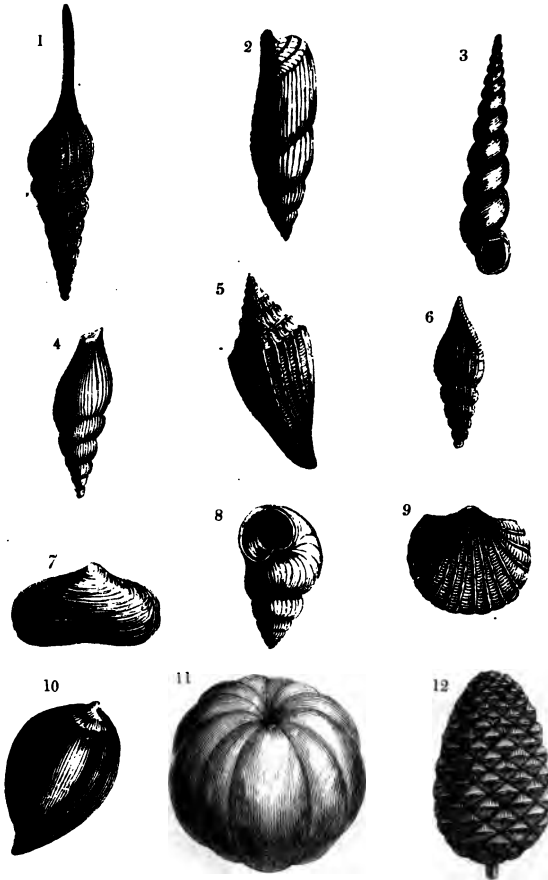
**EXTINCT ANIMALS RESTORED FROM THEIR FOSSIL
REMAINS.**

For Description, see page 252, opposite.



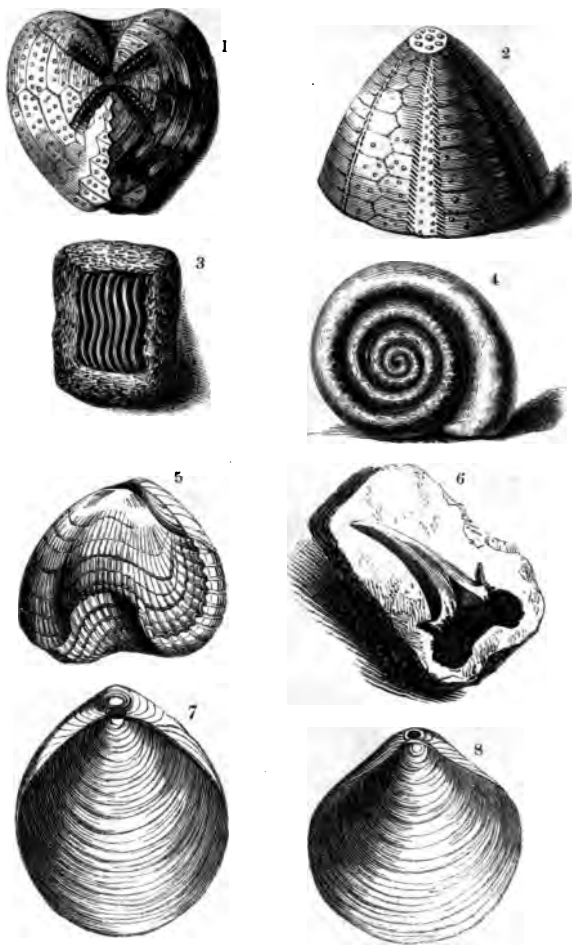
FOSSILS FROM THE CRAG, NEWER TERTIARY OR
PLEIOCENE FORMATION.

- | | |
|------------------------------------|-----------------------------------|
| 1. <i>Fascicularia aurantium</i> . | 8. <i>Venericardia scalaris</i> . |
| 2. <i>Littorina littorea</i> . | 9. <i>Modiola</i> . |
| 3. <i>Tubulipora</i> . | 10. <i>Bulla cylindracea</i> . |
| 4. <i>Voluta Lamberti</i> . | 11. <i>Saxicava rugosa</i> . |
| 5. <i>Patella æqualis</i> . | 12. <i>Tellina crassa</i> . |
| 6. <i>Cypræa avellana</i> . | 13. <i>Nassa elegans</i> . |
| 7. <i>Salaria similis</i> . | 14. <i>Paludina unicolor</i> . |



FOSSIL SHELLS AND SEEDS FROM THE LONDON CLAY, OR
EOCENE TERTIARY FORMATION:

- | | |
|----------------------------------|---|
| 1. <i>Fusus asper</i> . | 7. <i>Sanguinolaria compressa</i> |
| 2. <i>Ancillaria subulata</i> . | 8. <i>Paludina lenta</i> . |
| 3. <i>Turritella imbricata</i> . | 9. <i>Pectunculus scalaris</i> . |
| 4. <i>Limnaea longiscata</i> . | 10. <i>Hightea fusiformis</i> . |
| 5. <i>Voluta luctator</i> . | 11. <i>Cucumites variabilis</i> . |
| 6. <i>Rostellaria rimosa</i> . | 12. <i>Petrophiloides Richardsoni</i> . |



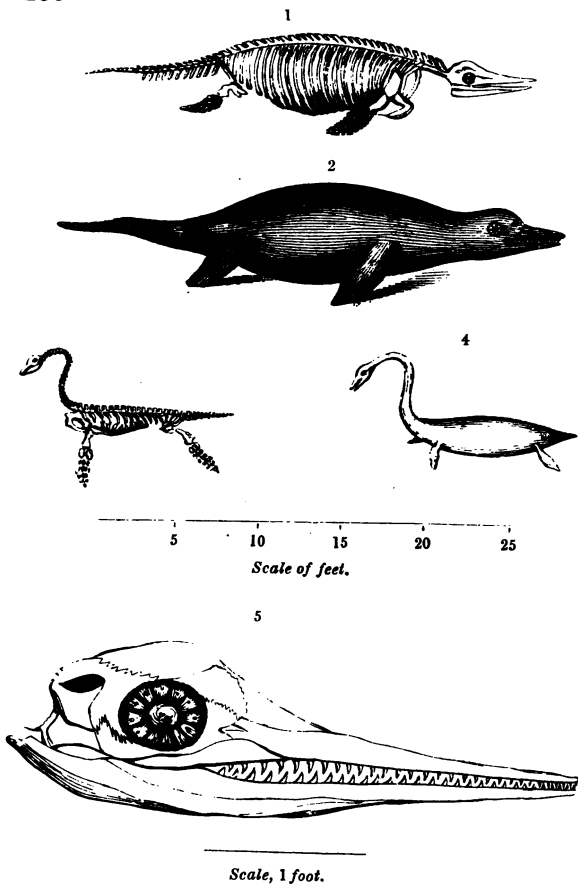
FOSSIL SHELLS FROM THE CHALK.

1. An Echinite, *Spatangus cor anguinum*.
2. Ditto, *Galerites albogalerus*.
3. A siliceous fossil, *Ptychodus polygurus*.
4. An Ammonite, or *Cornu ammonis*.
5. *Terebratula octoplicata*.
6. *Lamna elegans*.
7. *Terebratula semiglobosa*.
8. *Terebratula subrotunda*.



FOSSIL SHELLS FROM THE LIAS FORMATION.

1. An Ammonite,—*Ammonites obtusus*,—the dark part only partially occupied with dark brown crystals of carbonate of lime, and the lighter cellular spaces with the same matter, nearly transparent.
2. A Gryphite, *Gryphæa incurva*.
3. *Pleurotomaria Anglica*.



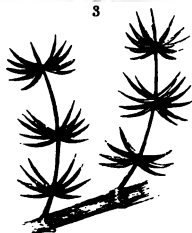
FOSSIL SAURIANS FROM THE LIAS FORMATION.

1. An *Ichthyosaurus communis*.
2. The same, with the fleshy covering restored.
3. A *Plesiosaurus* from the Lias.
4. The same, with the fleshy covering restored.
5. The head of an *Ichthyosaurus*, upon a larger scale, to exhibit the structure of the eye and jaws.



2. *Neuropteris gigantea*.

3. *Asterophyllites foliosa*.



4. *Sphenopteris trifoliata*.

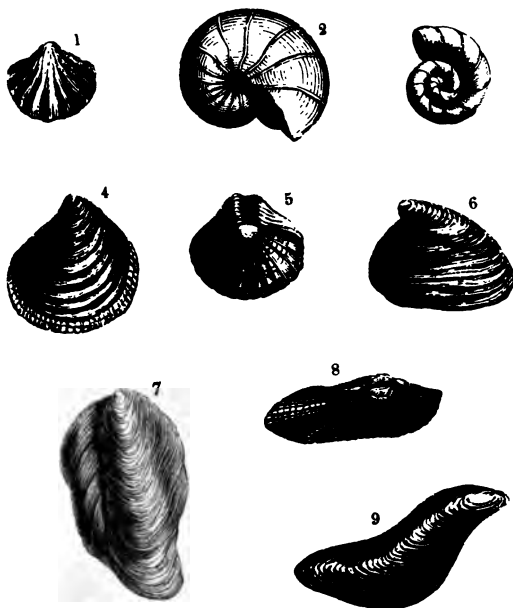
5. *Sphenopteris artemisiæfolia*.



6. *Sigillaria*.

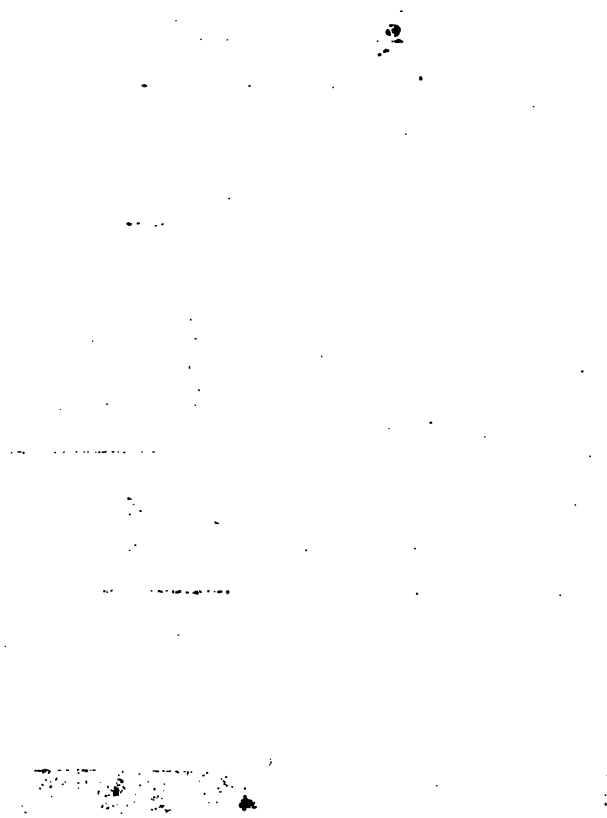


7. *Lepidodendron Sternbergii*.



FOSSIL SHELLS FROM THE LIAS FORMATION.

- | | |
|-----------------------------------|------------------------------------|
| 1. <i>Terebratula subserata</i> . | 6. <i>Pachyodon listeri</i> . |
| 2. <i>Nautilus decussatus</i> . | 7. <i>Hippopodium ponderosum</i> . |
| 3. <i>Ammonites colubrinus</i> . | 8. <i>Cucullea elongata</i> . |
| 4. <i>Plagiostoma giganteum</i> . | 9. <i>Gervillia</i> . |
| 5. <i>Spirifer verrucosus</i> . | |



SECTIONS OF THE STRATA TRAVERSED BY FOUR OF THE PRINCIPAL LINES OF RAILROAD FROM LONDON.

Section traversed by the GREAT WESTERN, from London to Plymouth.	Section by the GREAT NORTHERN, from London to Berwick.	Section from London, by the NORTH WESTERN, to Bealock Station, Dumfriesshire.
London and Plastic Clay. Chalk Clay Chalk Green Sand .	London. Slough Station. Reading. Doncaster.	London. London and Plastic Clay. Watford. Chalk

A GLOSSARY,

Explaining the terms which generally occur in geological works, and the nature and composition of the principal mineral substances.

Agate.—A siliceous or flinty mineral, which is considered a compound of many others, in which chalcedony mostly prevails over other ingredients, which consist of amethyst, quartz, cornelian, jasper, and opal. The varieties are ribbon agate, brecciated agate, fortification agate, from its resembling fortifications; mocha stone, moss agate.

Alabaster.—Compact gypsum, or sulphate of lime, which occurs extensively in the new red sandstone of England. There is another kind brought from Italy, which consists of a very pure carbonate of lime.

Albite.—Also called Cleavelandite, a siliceous compact felspar, generally of a grey or greyish white colour, and consisting of silice 70·7, alumina 19·8, soda 9·0, lime 0·2, oxide of manganese 0·1.

Alkalies.—Mineral substances which serve as bases to form salts with acids; soda and potash are such alkalies.

Alkaline Earths.—Earths which have the nature of alkalies, such as lime and magnesia.

Alluvium.—Earth, sand, gravel, and other transported matter deposited by running water in valleys and estuaries.

Alum.—A double salt, the sulphate of alumina and potash, the crystals of which contain nearly 50 per cent. of water.

Alum Shale.—A shale from which alum is made. The slate clay of the lias affords a shale of this kind on the coast of Yorkshire, near Whitby.

Alum Stone.—A mineral of a greyish white colour, and occasionally red. It occurs both massive and crystalline. Analysis, by Vauquelin:—Alumina 43·92, silice 24·00, sulphuric acid 25·00, potash 3·08, water 4·00

Alumina.—The plastic principle of clay, consisting of aluminum 12, oxygen 8.

Amalgam Native.—A mineral which occurs in a semifluid state, but sometimes massive or crystalline; it consists of 64 mercury, and 36 silver.

- Amazon Stone*.—A variety of felspar of a green colour.
- Amethyst*.—A violet-coloured quartz.
- Ammonia*.—A compound of nitrogen and hydrogen; 1 equivalent nitrogen 14, 3 equivalents hydrogen 3.
- Ammonites*.—The fossil shells of extinct spiral-chambered shell fish, of which there are many varieties, very abundant in the newer secondary strata.
- Amorphous*.—A term applied to shapeless minerals.
- Amygdaloid*.—A trap rock, often called toad-stone from its spotted appearance, resembling almonds.
- Analysis*.—The chemical operation by which a compound substance is separated into its constituent parts.
- Anhydrous*.—Minerals containing no water are called anhydrous.
- Anthracite*.—A non-bituminous coal of metallic lustre, which occurs both metallic and slaty, called also glance coal and culm. It is found in Staffordshire, South Wales, Scotland, and Kilkenny, Ireland. It burns without flame or odour, and consists of carbon 72·05, siliceous 13·19, alumina 3·29, oxide of iron 3·47. It is used for burning lime, and drying malt, &c.
- Anticlinal axis*.—When the strata are raised so as to form a ridge of hills or mountains, the line traversing the centre through the whole length is called its anticlinal axis.
- Antimony*.—A metal of a silvery white colour, and very brittle, whose specific gravity is about 6·7. It occurs principally as a sulphuret, that is, mineralized with sulphur, in which state it is of a light lead grey colour. When purified it is called regulus of antimony. It is much used in the arts and in medicine. 3 parts lead and 1 of antimony form the metal used for types.
- Apatite*.—Mineral phosphate of lime. It is of various colours, white, yellowish white, green, blue, and red. It occurs both massive and in six-sided crystals; when massive it is called phosphorate. It is found in the crevices of slate rocks, and in the South of Spain in considerable masses, which according to Klaproth consists of lime 54·28, phosphorus 45·72. It is the principal ingredient in bone earth.
- Arenaceous*.—Sandy, consisting of sand; from *arena*, sand.
- Argillaceous*.—Composed of clay.
- Argillo-Ferruginous Limestone*.—Those peculiar limestones which are called cement stones or hydraulic limestones, of which the cement stones of the London clay, and Aberthaw, and other lias limestones, are specimens. They consist of various proportions of carbonate of lime, alumina and siliceous, oxide of iron and water. The nodules found in the London clay form the best cement found in England. A variety called calp, is composed of carbonate of lime 68, siliceous 18, alumina 7·5, oxide of iron 2, carbon and bitumen 3, water 5.

Arragonite.—A variety of carbonate of lime, so called from Arragon, in Spain.

Arsenic.—This metal occurs, native or pure, as a sulphuret, and as an oxide. Native arsenic is of a grey lead colour inclining to white, exceedingly brittle, specific gravity 5·88. The oxide of arsenic is of a pure white, and is the very poisonous substance known by that name, and called by chemists arsenious acid. Arsenic is found combined with the ores of various metals, and particularly with that of cobalt, from which it is usually obtained by sublimation. Its combining proportion is 37. It is used to form alloys with other metals, to which it imparts hardness; one tenth of it in copper produces an alloy of silvery whiteness. There are two sulphurets of arsenic, one called realgar, which is of a brilliant red or scarlet colour, and another called orpiment, of a bright yellow. The first consists of arsenic 69, sulphur 31; and the second, arsenic 62, sulphur 38.

Asbestos.—A siliceous mineral, extremely difficult of fusion, some species of which are fibrous, and so flexible as to allow of being spun and formed into a web like cloth. Its specific gravity is about 3, and it consists of silica 59, alumina 3, lime 9, magnesia 29. The varieties are called amianthus, mountain cork, and mountain leather.

Asphalte.—A compact bitumen found in various parts of the world; in France, Neufchatel, the Dead Sea, Barbadoes, and Trinidad. In the latter island is a lake of it, the thickness of which is unknown. It is of a brownish black colour, and shining resinous lustre. It consists principally of bituminous oil, hydrogen and charcoal, and when burnt leaves a small quantity of ashes.

Augite, or Pyroxene.—A mineral found in volcanic products, and what are called igneous rocks, of a green, or brown, or brownish black colour. There are several varieties, which are variously compounded. A black specimen analysed by Klaproth gave the following:—Silica 58, alumina 5, lime 24, magnesia 8·75, oxide of iron 12, manganese 1. It fuses easily into a dark coloured glass. It is found in the basalt rocks of Teesdale, in the trap rocks round Edinburgh, and in the Orkneys and Hebrides.

Barytes.—A ponderous mineral which occurs massive and crystallized, and both as a carbonate and sulphate. The crystals of carbonate of barytes are six-sided, whitish or grey, and greenish white; specific gravity 4·3; composition, barytes 78, carbonic acid 22. It melts with great heat into a white enamel. It is found abundantly in the lead mines of the north of England, and in Shropshire, and Flintshire.

The sulphate of barytes, called heavy spar, is found also both massive and crystallized; its specific gravity, 4·7; and it

consists of barytes 67, sulphuric acid 33. It melts before the blowpipe into a white enamel. It occurs in the mines of Cornwall, at Matlock in Derbyshire, at Nutfield, Surrey, in the limestone of Babbicombe in Devon, in a lead mine in Ayrshire, and in the granite of Ireland. There are many foreign varieties of this mineral. Barytes is called by the chemists an alkaline earth; its equivalent number is 76, and it consists of barium 68, and oxygen 8.

Basalt.—A trap rock of nearly a black colour and very firm texture; it is composed of two principal minerals, felspar and augite; its specific gravity is 3; composition, siliceous 44·5, alumina 16·75, lime 9·5, magnesia 2·25, soda 2·6, oxide of iron 20, oxide of manganese 0·12, water 2. It is found traversing in dykes the strata of sandstone, the coal measures, and most of the secondary rocks in England; it occurs also extensively in the south of Scotland and in Ireland. It is both amorphous and columnar, and in the latter state forms part of the Salisbury Crags at Edinburgh, and the Giants' Causeway in Ireland, and Fingal's Cave in the Island of Staffa. Decomposed basalt, called *tarras*, is used as a cement.

Basin, in geology, is a term used to express a hollow, in which strata are deposited, such as the chalk basins of London and Paris.

Belemnite.—An extinct genus of molluscos animals, with a long, straight, and chambered shell, pointed at the end, abounding in the oolites.

Beryl, or Aquamarine.—A crystallized siliceous mineral, of a yellow, green, or blue colour. It occurs in granite and in primitive rocks, in Kinloch, Ramoch, and Cairn Gorm, Aberdeenshire; mountains of Dundrum, County of Dublin, and Wicklow, Ireland. It is considered a species of emerald. Its composition is stated by Vauquelin to be, siliceous 68, glucine 14, alumina 15, lime 2, oxide of iron 1. Specific gravity 2·67.

Bismuth.—This metal occurs native, and also as a sulphuret, oxide, and carbonate. Native bismuth is of a silvery white tinged with red, easily melts in the flame of a candle, and with a stronger heat volatilizes as a white powder. Specific gravity 9. It occurs with ores of cobalt and nickel in primitive rocks, in several mines of Cornwall, as do also the several ores above mentioned. An alloy of 8 parts of bismuth, 5 of lead, and 3 of tin, fuses at 212° Fahr. The equivalent of bismuth is 71.

Bitumen.—Mineral pitch, a blackish brown inflammable substance, which burns with a bright flame, and agreeable bituminous odour, depositing much soot.

Bituminous Shale.—A clay impregnated with bitumen, often occurring in coal mines.

Blende.—Sulphuret of zinc occurs crystalline and amorphous;

colour various; brown or yellow, yellowish, reddish, red, and blackish red. Specific gravity 4; composition, zinc 68·48, sulphur 23·16, iron 8·08. Infusible before the blowpipe.

Blende Coal.—See Anthracite.

Borax.—Occurs in prismatic crystals of a whitish colour varying with a tinge of blue or green, and consists of boracic acid 36, soda 17, water 47; found chiefly in Thibet, also Ceylon, Tartary, Lower Saxony, and Potosi in Peru. Borax is extensively used in the arts as a flux, particularly in soldering.

Boron.—The basis of boracic acid.

Boulders.—Large, water-worn, and rounded blocks of stone.

Breccia.—A mass of stone or rock composed of angular fragments, united by carbonate of lime, often forming a beautiful marble.

Calamine.—Carbonate of zinc, the ore of zinc, a greyish or yellowish mineral. Specific gravity 4·3. Composition of amorphous calamine is 64·8 oxide of zinc, 35·2 carbonic acid.

Calcaire Grossier, or Coarse Limestone.—A stratum of limestone in the Paris Basin.

Calcareous.—Consisting of carbonate of lime.

Calcareous Rock.—Limestone, marble.

Calcareous Spar.—Crystals of carbonate of lime.

Calcination.—The burning of earthy substances, as the burning of limestone.

Carbon.—The solid inflammable substance of coal and wood. Charcoal and lamp-black are specimens of impure carbon; it exists in a state of the greatest purity in the diamond.

Carbonate of Lime.—The earthy salt composed of carbonic acid and lime, of which statuary marble is nearly a pure specimen. 1 atom of lime 28, and 1 atom of carbonic acid 22.

Carbonic Acid Gas.—The gas formed by the combustion of carbon, by the fermentation of beer, and the burning of lime.

Carboniferous.—A term now generally applied to those rocks supporting the coal measures, particularly the mountain limestone which usually supports them.

Cataclysm.—A deluge.

Cerium.—A rare metal, but very little known with certainty.

Chalcedony.—A siliceous mineral resembling common flint.

Chalk.—An extensive formation of carbonate of lime, the uppermost of the secondary rocks. It consists principally of carbonate of lime, containing numerous fossils. The upper beds are soft, and contain bands of flints; the middle beds are harder, with few or no flints; and the lowermost bed contains a considerable portion of clay, and assumes the character of a marl stone.

Chert.—A flint stone which occurs in beds in the green-sand at Folkstone, the Isle of Wight, and the Black Down of Somer-

set and Devon; also in nodules and beds in the mountain limestone of Derbyshire.

Chlorides.—Compounds formed by the union of chlorine with metals and other substances. Common salt is a chloride of sodium.

Chlorine.—One of the elements of muriatic acid, of which hydrogen is the other. Its equivalent is 36, in which proportion it unites with metals and other substances to form chlorides. In its gaseous state it is a suffocating and offensive gas.

Chlorite.—This mineral occurs crystallized, compact, slaty, and earthy. It is usually of a dark green colour, and sometimes of a yellowish green. It is found in primitive mountains. Compact chlorite traverses in veins the clay slate of Arran and Bute in Scotland. The composition is, siliceous 26, alumina 8.5, magnesia 8, oxide of iron 43, muriate of soda 2. It occurs in the tin mines of Cornwall, and is the mineral which stains blue slates in spots and veins.

Chromium.—A metal remarkable for the beautiful colours produced by its various compounds. It is found mineralized with iron, as a chromate of iron. Its preparations are extensively used in painting and dyeing. Its equivalent is 28, and with 3 equivalents of oxygen it forms chromic acid. The principal colours of its compounds are red, green, and yellow, all very beautiful.

Clay.—A compound earth, consisting chiefly of alumina and silica, in a state of intimate mixture, often containing carbonate of lime and magnesia. In the purest clays, such as the pipe-clay and porcelain clay, the silica is at least equal to alumina or plastic principle; and in the coarse kinds, such as are used for common pottery and the making of bricks, the silica is in excess, and much of it in the state of sand of different degrees of fineness. The common impure clays contain oxide of iron, to which they owe their brown and red colour. In their indurated state clays form those hard beds called shales, which constitute a large portion of the coal measures. Those clays in which carbonate of lime much abounds are called marles.

Clay Slate.—A primary rock which appears to have been formed from clay, and has since undergone an extreme degree of induration.

Clinkstone or Phonolite.—A felspathic trap rock, which is sonorous when smartly struck.

Coal.—Of this mineral there are many different kinds, which, however they may vary in external properties, appear to be of vegetable origin. For some time this was a much disputed point, but recent investigations by the microscope having revealed its organic structure leave no longer any doubt on the subject. Dr. Thompson has distinguished four

different kinds, of which he has given the following analysis. The more obvious difference in the several kinds consists in the degree of hardness and the manner in which they burn. The Newcastle coals, and some of those of Yorkshire and Somerset, undergo a sort of semifusion in the fire, and are called caking coal; while others, as those of Shropshire and Staffordshire, burn away with a lively flame, and without adhering. The Cannel coal is remarkable for clean even fracture, for not soiling the fingers when handled, and for burning with a bright flame. It is found at Preston in Lancashire, and near Newcastle; at the Clee Hill, Shropshire, and near Edinburgh. Cannel coal receives a good polish, and is formed into snuff-boxes and other articles.

	Carbon.	Hydrogen.	Nitrogen.	Oxygen.
Newcastle or caking coal	75.28	4.18	15.96	4.58
Splint, or brown hard coal from Glasgow, used for making coke and smelting iron	75.00	6.27	6.25	12.05
Cherry or sift coal from Glasgow, of the same kind as the Staffordshire coal	74.45	12.40	10.22	2.93
Cannel coal	64.72	21.56	10.72	

In these analyses the inorganic matter or ashes are not mentioned, but they are known to differ very much in quality, from 1 to 12 per cent., the Newcastle coals containing the least of any.

Coal, Bovey, or Lignite, or Brown Coal.—This coal occurs at Bovey Tracey in Devonshire, where it forms six beds, interstratified with clay. It is of a brown colour, and exhibits more or less the structure of wood: it also occurs in Fife and Midlothian, Scotland. It burns with much smoke, resembling in smell that from peat. It belongs to the tertiary deposits, and is found in Germany, and France, and most other European countries. At Mansfeldt in Thuringia, and in the circles of Saal and Leipsic, are beds of from 20 to 40 feet thick, and of several miles in extent.

Coal Formation.—Strata containing coal, chiefly consisting of sands and shales, and sometimes limestone.

Coal Glance. See Anthracite.

Cobalt.—A brittle metal of a reddish grey colour and metallic lustre. Its specific gravity is 7.834. It is generally found mineralized either with arsenic or sulphur, but chiefly with the former. From this is formed the impure oxide of cobalt, the zaffre of commerce, which when melted with 3 parts of acid and 1 of potash and afterwards ground very fine, produces the blue powder called smaltz, employed to give a blue tint to paper and linen, and for painting porcelain, &c. The ores of Cobalt occur in primary and secondary mountains.

Combustion.—The violent chemical action called burning, by which the elements of the burning substance are not destroyed, but enter into combination with oxygen.

Compact.—A term applied to minerals or stones, which present no appearance of crystals; thus common limestone is called compact limestone, to distinguish it from marble, which is a crystalline limestone.

Conformable.—A term applied to the strata when they lie evenly upon one another, as opposed to such as rest upon the broken edges or sloping surfaces of those beneath.

Conglomerate, or Pudding Stone.—Pebbles, or rounded fragments of rock, cemented together by stony matter, which sometimes forms immense masses.

Copper is a red, ductile, and malleable metal of great tenacity, whose specific gravity is 8·667; it undergoes but little change in a dry air, but with moisture becomes oxidized, and is converted into the green substance called carbonate of oxide of copper; at a red heat it is converted into a black oxide. The ores of copper are numerous, but the most abundant ore is the sulphuret of copper and iron, which is extensively raised from the mines of Cornwall. It is frequently found native in large irregular masses.

Phillips gives the following analysis of the crystallized yellow copper ore (copper and iron pyrites) of Cornwall. Copper 30·10, iron 32·10, sulphur 36·16, earthy matter 0·50, lead, arsenic, and loss 2·14. The ordinary ore is much mixed with quartz, from which it is separated by stamping and washing. The separation of the copper from the ore is an operation of great skill and expense.

Copper ore is found in great abundance in many other countries of Europe, South America, Japan, and recently in South Australia. At no very remote period the Cornish miners in search of tin, threw aside the copper ore from ignorance of its value.

Coprolite.—The petrified dung of Saurian animals, found abundantly in the lias formation at Lyme Regis, and recently in the green-sand of Kent and Sussex. It principally consists of phosphate of lime.

Cornbrash.—An imperfect rubbly limestone of the Oolitic series.

Cornstone.—A red limestone of the old red sandstone, or Devonian system.

Corundum.—An exceedingly hard and ponderous crystallized mineral; specific gravity about 4, of which the sapphire and ruby are beautiful specimens. According to Klaproth's analysis, the sapphire consists of alumina 98·5, lime 0·5, oxide of iron 1; and according to Chenevix the analysis of the ruby gives alumina 90, silice 7, oxide of iron 1·2. Common corundum and emery are of very similar composition.

- Cosmogony*.—A word signifying the theory or speculation respecting the formation of the earth.
- Cotham Marble*.—A lias limestone, which, when polished, exhibits the appearance of trees and landscapes.
- Crag*.—The uppermost of the English tertiary strata on the coast of Norfolk and Suffolk, provincially so called.
- Crater*.—The circular hollow at the summit of a volcanic mountain, from which the burning matter is ejected.
- Cretaceous*.—Chalky, consisting of chalk.
- Crop out*.—A miners' term, signifying the appearance of the edge of an inclined stratum at the surface.
- Crystalline*.—That structure of mineral bodies produced by an assemblage of minute crystals, as in statuary marble and alabaster.
- Crystallization*.—That chemical action by which salts and other crystallizable substances assume a regular geometrical form, each particular salt or substance taking a constant, peculiar, and definite shape, by which it is externally distinguished from others.
- Debate*.—A gush of waters through their confining banks, bearing along the confused materials of the obstacles which opposed their progress.
- Deltas*.—The silty and sandy deposits at the mouths of great rivers, forming extensive tracts of land of many hundred square miles, as those of the Nile, Ganges, Niger, Mississippi, &c.
- Diamond*.—The hardest of all known substances. Diamonds are always found in detached crystals, and are either colourless, or of a yellowish, bluish green, different shades of brown, blue, or red colour. They are composed entirely of carbon, and are dissipated by burning, by which they are converted into carbonic acid. Specific gravity 3.5. Diamonds are chiefly found in India, and the most productive mines are those of Golconda and Masulipatam. They are also obtained in Borneo and Brazil, where, as well as in India, they are found in beds of ferruginous sand and gravel. The diamonds obtained at Pastael, near Golconda, at the foot of the Ghaut mountains, are the most prized. These mines are situated at the conflux of two rivers, and have produced the most celebrated diamonds, amongst others the remarkable Pitt or Regent diamond, the finest of the crown jewels of France, weighing nearly an ounce, which was purchased for 2,500,000 francs, or nearly 100,000*l*. One of the largest known diamonds was in the possession of the late Empress of Russia, which was of the size of a pigeon's egg, and weighed nearly 1 ounce and a third; but a still larger was in the possession of the Raja of Mattan, which weighed 2 ounces and 169

grains, and is said to be of the finest water, and for which Mr. Stewart offered an immense sum in vain.

Diluvium.—A term commonly given to ancient beds of gravel or drift, which often extensively cover the regular strata in wide valleys and plains, and also are found on high ground and the summits of hills.

Dip.—The inclination of strata from the horizontal line.

Dolerite.—A variety of trap rock composed of augite and felspar.

Dolomite.—A mineral resembling primitive limestone, but is much softer. It is generally white, with a tinge of yellow or grey. Consists of carbonate of lime and magnesia. That of the Apennines consists of 59 carbonate of lime, and 40 carbonate of magnesia, with a variable portion of iron. It occurs in the south-west of Iona, one of the Western Isles, where it is 40 feet wide, between vertical walls of horn-blende rock. There is another variety called compact dolomite, which is of a snow-white colour, and consists of carbonate of lime 70·50, carbonate of magnesia 29·50.

Dunes or Downs.—Low hills of sand which in many places are blown up from the sea-shore, as at St. Ives' Bay, and Perranzabulo, in Cornwall.

Dykes.—Veins or masses of trap rocks which have penetrated the softer strata, and sometimes rise above them like a wall, and are called dykes from a provincial term for a wall.

Emerald.—A gem of a beautiful green colour, often of great intensity, harder than quartz, and much resembling the beryl, though less hard. Its analysis by Vauquelin gives silice 64·5, alumina 16, glucine 13, lime 1·6, and oxide of chrome 3·25, to which latter substance it is supposed to owe its colour. The finest emeralds are found in Peru, at Tunca or Santa Fé. A beautiful specimen of emeralds was presented to the Church of Loretto by one of the Spanish kings; it consists of a mass of white quartz interspersed with emeralds, of more than an inch in diameter.

Emery.—An extremely hard mineral, considered to be a variety of corundum, which it resembles in composition: its specific gravity is 3·66. Analysis by Tennant: alumina 86·5, silica 3·6, oxide of iron 4. It is said to be found sparingly in a ravine in Glenmalur, Wicklow, Ireland; but commerce is supplied from Smyrna and Naxos.

Eocene.—The lowest or first of the tertiary strata, so called by Sir Chas. Lyell, and represented in England by the London clay.

Escarpment.—The abrupt and steep slope or ridge of a hill.

Estuaries.—The tideways of rivers, and other inlets of the sea.

Fault.—A term used by miners for those dislocations of the strata often found in mines, by which their continuity is

broken, and by which the strata is depressed or raised : often the cause of great embarrassment to miners, as these displacements sometimes amount to many hundred feet.

Felspar.—A very abundant glassy mineral, constituting a large portion of all granites and gneiss rocks and some trap rocks ; it is of various colours, white, yellowish green, and red. In granite its crystals are generally evenly blended with those of quartz and mica, but is sometimes large and two or three inches long, as in that of Heytor, Devonshire, used for the basements of houses in London, and in the construction of London Bridge. Its specific gravity is 2·54 ; composition, silice 62·83, alumina 17·02, lime 3·0, potash 13·0, oxide of iron 1. There are several varieties, but they are all nearly of the same composition. It fuses with borax into a semi-transparent glass.

Felspar, Compact. See Albite.

Flint.—A siliceous mineral, found in great abundance in the upper stratum of chalk, generally of a blackish colour, but sometimes yellow or greyish. Harder than common quartz, admits of easy cleavage in any direction. Specific gravity 2·594 ; and consists of silice 98, lime 0·5, alumina 0·25, oxide of iron 0·25 ; infusible, but whitens when burnt. It is often found to enclose fossil sponge and other organic remains. Flint constitutes the pebbles of the tertiary strata, which forms extensive beaches in the south of England, of which the Chesil Bank of Portland is the most remarkable.

Some flints are of recent origin, and 126 silver coins were found imbedded in flints at Grincoe in Denmark, and an iron nail at Potsdam in Prussia.

Fluor Spar, or Fluoride of Lime.—A mineral generally known by the name of Derbyshire Spar. It is sometimes perfectly transparent, also white, grey, and various shades of blue, green, red, yellow, and purple ; many of the specimens are exceedingly beautiful, and are manufactured into various ornamental articles. It is harder than calcareous spar ; its gravity is about 3, and it is composed of lime 67·75, and 32·25 fluoric acid ; but the colourless and transparent kinds consist of lime 72·137, and fluoric acid 27·863. It fuses with borax into a transparent glass. Fluoride of lime is also found in a compact and earthy state. It is found in abundance in the copper mines of Cornwall, and the lead mines of Derbyshire and the north of England.

Fluviatile.—Belonging to rivers ; from *fluvius*, a river.

Formation.—A group or series of rocks, having some common character.

Fossils.—The remains of plants or animals buried and petrified in the earth.

Fullers' Earth.—A soft earthy mineral, formerly used for fulling

cloth, but now superseded by soap. Composition, siliceous 53, alumina 10, lime 0.5, magnesia 1.25, oxide of iron 9.5, common salt 1, water 24. Found at Deptling, Kent, and Old Down, near Bath, and Nutfield, in Surrey.

Fusion.—The melting of mineral substances by heat.

Galena.—Sulphuret of lead, the principal ore of lead, of which there are many varieties. Galena is of a grey colour and brilliant metallic granular structure, easily broken. Dr. Thompson gives the following analysis of a specimen from Durham:—Lead 85.13, sulphur 13.02, and iron 0.50. It melts before the blowpipe, emitting a sulphurous odour, leaving a metallic globule of lead. It is found in primitive and secondary mountains. The mines of England are very productive. It occurs in the mountain limestone of Northumberland, Durham, Derbyshire, and Flintshire; in clay slate in Cornwall, and Devonshire; and in schistose rocks in Shropshire and Wales. In Scotland it is found in granite, gneiss, and the sandstones of the coal formation.

The common galena contains a small quantity of silver, but that termed argentiferous, affords considerable but varying quantities; and one mine called the South Hoo, near Beeralstone on the Tamar, lately yielded 135 ounces of pure silver per ton.

Garnet.—Under this name are arranged many minerals, consisting of nearly the same materials, of which the precious and common garnet is the principal.

Precious garnet is of a beautiful red colour of various shades, sometimes tinged with yellow or blue. It is a crystalline mineral, harder than quartz, and often transparent. Specific gravity 4.3; and consists of silica 35.75, alumina 27.25, oxide of iron 36, oxide of manganese 0.25. It is found in primitive rocks, chiefly in mica slate.

Common garnet differs from the precious in not being transparent, or only translucent. It is harder than quartz, and consists of silica 43, alumina 16, lime 20, oxide of iron 16. Common garnets are very abundant in the crystalline rocks, and are found in Cornwall, Cumberland, Scotland, and Ireland.

Gault.—A provincial term for those beds of clay which separate the upper and lower green-sand strata.

Geognosy.—A word having the same meaning as geology, or a discourse of the earth.

Glaciers.—Those accumulations of ice and hardened snow which occupy the elevated bosoms of lofty mountains, and which particularly abound in the Alps. The gradual subsidence of these enormous masses has the effect of wearing away the rocks over which they pass, and producing the immense quantity of detritus brought down by the waters which issue from their lower extremities.

Glacis.—An easy slope of the earth ; a term taken from the science of fortification.

Glance Coal.—See Coal.

Gneiss.—A crystalline schistose rock of the primary order, and considered to be a sedimentary metamorphic rock, changed by the action of heat upon shale or slate. It consists generally of the same minerals as granite, namely, quartz, felspar, mica, and hornblende in a laminated form and often much contorted.

Gold.—This precious metal occurs massive and crystalline, more or less alloyed with other metals, chiefly copper and silver. When pure it is soft, malleable, and flexible, and of a pale yellow colour, and is very remarkable for resisting oxidation, or the very weak affinity it has for oxygen. It is found in threads, grains, and sometimes in masses of several pounds weight ; specific gravity 19. It occurs in the sands of many rivers, particularly those of Africa and America, and has been recently discovered in immense quantity in the alluvial soils of California. The gold mines of La Plata are very numerous, and large quantities are brought from the Ural mountains in Russia. Before the discovery of gold in California, the mines of America were computed to afford 30,000 pounds weight annually. Small quantities of gold have been found in the alluvial deposits of Cornwall, at Glen Tilt in Scotland, and in Wicklow, Ireland, where one mass was discovered which weighed 22 ounces.

Granite.—An unstratified rock, essentially consisting of quartz, felspar, and mica or hornblende, confusedly blended and unstratified. It is a hard, igneous rock, and appears to underlie all others. It however often assumes the character of a trap rock, by penetrating, altering, and upheaving the incumbent stratified rocks. When the mica is replaced by hornblende the rock is called Sienite, from Siene in Upper Egypt, where this rock forms the cataracts of the Nile. Granite forms the central part of many ranges of lofty mountains, underlying all other rocks and towering above them in sharp inaccessible peaks, a character which is strikingly exhibited in the Alps. Granite is not abundant in England, the principal masses occur in Devon and Cornwall, from Dartmore to the Land's End ; the Malvern Hills, Worcestershire ; Mount Sorrel, Leicestershire ; and the western part of Cumberland. In Scotland it is more extensive, and occupies a large part of Aberdeenshire, with detached portions along the range of the Grampians to Loch Etive on the western coast, Cairn Gorm forming one of the loftiest summits. The finest specimens used for building are brought to London from Aberdeen and Peterhead. Granite also

occupies a considerable portion of the counties of Wicklow and Wexford, in Ireland, extending from the south of the bay of Dublin nearly to New Ross, in the latter county. It also occurs on the coast of Galway and Donegal on the west and north, and of Down on the east, with several detached portions. The granite of which Waterloo and London Bridges are built, was supplied from Aberdeen, Dartmoor, and the west of Cornwall. Gunnis lake, at the extremity of the estuary of the Tamar, affords a granite nearly white and of beautiful grain.

Graphite, Plumbago, Black Lead.—This well known mineral is a carburet of lead, and consists of carbon 89·9, iron 9·1; its specific gravity is about 2. It is found in primitive rocks, and the most valuable kind occurs in a schistose rock in Borrowdale, Cumberland. When heated the carbon burns away without smoke, leaving a red oxide of iron.

Gravity, Specific.—The weight of a given volume of a solid, fluid, or gas, as compared with some standard. 1,000 parts by measure of water at 60° Fahr. is the standard for fluids and solids; and 1,000 parts of atmospheric air at the same temperature is the standard for gases and vapours. So that when the specific gravity of a solid is stated at 1,500, it is $1\frac{1}{2}$ times the weight of water; or as 1,600, it is one and six-tenths heavier than water.

Green Sand.—The stratum of sand between the chalk and the wealden formation.

Green Stone.—One of the trap rocks, composed of hornblende and compact felspar, sometimes including other minerals. It is of a greenish aspect, sometimes grey or reddish. It occurs in most trap countries, as in Cornwall. A rock of green stone also occurs in Charnwood Forest, Leicestershire.

Greywacke.—A German name for a numerous class of sedimentary slaty rocks, now distinguished by English geologists by the names Devonian, Silurian, and Cambrian slates.

Grit.—A sandstone composed of coarse-grained siliceous sand, of which we have familiar instances in our common grindstones, and in the Yorkshire flagstones in the streets of London, which are brought from the millstone grit quarries in Yorkshire.

Gypsum.—Sulphate of lime, selenite. There are several varieties of this mineral. When compact it is called gypsum or plaster of Paris, and when crystallized, selenite. Its specific gravity is 3; and it consists of lime 32·7, sulphuric acid 46·3, water 21. Gypsum occurs abundantly in the red marl of Somerset, Nottingham, Derbyshire, and in the salt deposits of Cheshire; it is generally white with shades of red, brown, and yellow, and of a soft yielding texture. The purest specimens are called alabaster, which is wrought into vases

and other ornaments. When calcined its water is dissipated, and being reduced to powder it is then called anhydrous gypsum, in which state it is extensively used for the mouldings of ceilings, and to form casts of statuary, as it has the property of setting rapidly when mixed with water. Selenite or crystallized sulphate of lime, is semi-transparent, and formed of extremely thin laminæ or plates, which can be easily separated with the nail. It occurs in separate crystals of various sizes, dispersed in deposits of clay, and abundantly in the London clay.

Hæmatites.—Ores of iron (see Iron Ore).

Heavy Spar.—Sulphate of barytes (see Barytes).

Hornblende.—This substance occurs crystallized, massive, and slaty. The crystallized hornblende is of a dark bottle-green colour, approaching to black. Its specific gravity is 3·6, and it consists of silex 42, alumina 12, lime 11, magnesia 2·25, oxide of iron 30, manganese 0·25, water 0·25. It fuses into a black brilliant glass. Hornblende is an abundant mineral in the so-called igneous rocks. It occurs in the green stone of Cornwall and the basalts of coal formations, in the sienite, mica slate of Scotland, and in the trap rocks of that country.

Hornstone.—A siliceous stone, much resembling flint.

Hyacinth.—A precious stone of various shades of red, transparent or translucent, and consists of zircon, silex and oxide of iron.

Hyalite.—A siliceous mineral, consisting of silica 92, water 6·3, with a small trace of alumina. It is found on basaltic rocks.

Hydrates.—Minerals chemically united with water. Many minerals contain water in a solid state.

Hypersthene.—Labrador hornblende, and of similar composition to hornblende.

Iceland Spar, or double refracting spar.—A very pure specimen of carbonate of lime.

Infusory Animalcules.—Microscopic, or very minute living creatures, found in stagnant or putrid waters.

Iolite.—A mineral of a purple or bluish violet colour, very hard and scratches quartz. Its specific gravity is 2·56, and it is composed of silex 42·6, alumina 34·4, lime 1·7, magnesia 5·8, oxide of iron 1·5, oxide of manganese 1·7. It fuses into a transparent glass.

Iridium.—A rare metal, discovered amongst the ore of platinum; it is found alloyed with osmium. The specific gravity of the alloy is 19·5, equal to that of gold.

Iron Ore.—Iron rarely occurs native, and the meteoric iron which approaches nearest in appearance to pure iron, contains always nickel or cobalt. In combination with oxygen or sulphur, however, it is the most abundant of all the metals, being almost universally diffused, as it constitutes the colouring matter of all soils, and is contained in all

plants and animals, and is essential to their existence. The ores of iron are numerous, but the most valuable and abundant are the following:—The red oxide of iron, or red Hæmatite; the brown oxide, or hydrated peroxide of iron; the black oxide, or magnetic iron ore; and the clay iron ore, which is a carbonate of protoxide of iron mixed with siliceous and aluminous earths and other foreign matter. The three former are found in primitive strata, and afford the superior iron of Sweden and India; the latter is the ore from which almost all the British iron is derived, and is abundantly found in the secondary strata, but principally in the coal measures from which most of the British iron is derived. Native meteoric iron has a metallic lustre, is malleable, and very tough; specific gravity 7·40. A specimen found in Siberia contained 1·5 per cent. of nickel; another from Mexico contained 3·25 per cent.; most of those analysed contain more or less of that metal, and some contain chrome and cobalt. A large mass of this iron was found by Professor Pallas, on the top of a mountain, weighing 1,680 Russian pounds, which had all the valuable properties of iron as to malleability, flexibility, &c. A mass found in the desert of Sahara, in Africa, yielded 4 per cent. of nickel. Various specimens of meteoric iron have been observed in different countries, but the largest mentioned is one found in the Vice-royalty of Peru, in South America, which weighed 15 tons. A mass found in Louisiana exceeded 3,000 pounds weight, and was covered with a black crust. A mass which was found at Agram, in Austria, was said to have been seen to fall from the atmosphere; and that found by Pallas, above mentioned, was also reported by the natives to have fallen from the sky. Many interesting observations on meteoric stones or *ærolites* leave little or no doubt that all such masses are portions of planetary matter, which revolves round the sun like the great masses of the planets, and which having come within the sphere of the earth's attraction, have been drawn down to it.

The Red Hæmatite, or Fibrous Red Iron Ore, is generally of a bluish or iron-grey externally, but internally of a red or brownish red colour, with a fibrous texture and metallic lustre. It mostly occurs in roundish or globular masses; specific gravity 4·7—5. A specimen analysed by Daubuisson yielded 90 per cent. of oxide of iron, 2 siliceous, 1 lime, and 3 water, with a trace of manganese. It occurs abundantly in Devonshire at Heytor; in the Forest of Dean, Gloucestershire; in Cumberland; in Lanarkshire, in veins of sandstone; and in green stone, at Salisbury Crags, Edinburgh. The iron obtained from it, both cast and malleable, is of excellent quality; and the best qualities, both of plate-iron and wire,

are made from it. When this ore is reduced to fine powder it is extensively employed in polishing metal. The ore obtained in Devonshire is smelted with common clay ores in the furnaces of South Wales, and that of Scotland is also used with the ore of the country at the Carron and Glasgow Iron works.

Fibrous Brown Iron Ore, or Brown Hæmatite, is of a blacker brown, and often of a steel-grey colour, finely fibrous and sometimes of a silky lustre. It occurs in roundish masses and stalactic tubes, and is of brittle texture. Specific gravity 3·7 to 4·0. Analysis, peroxide of iron 80·25, water 15, silica 3·75, according to Vauquelin. It occurs in Bohemia and Saxony, where it is extensively wrought. It is also found in the mines of Cornwall, in Cumberland, Lanarkshire, Scotland, the Shetland Isles, and the Orkneys. It affords harder iron than the red ore, and good steel.

Magnetic Iron Ore.—This ore occurs compact and crystallized. Its colour is black, with a metallic lustre. Specific gravity 4·4; and it consists, according to Berzelius, of protoxide of iron 28·14, and peroxide 71·86. It is highly magnetic, especially the massive or native loadstone. This ore occurs in the parishes of Roach and St. Stephen's, and at Trelerwell near Penrhyn in Cornwall, and at Wicklow in Ireland. It is found in many primitive countries in beds and masses, and associated with hornblende, primitive limestone, pyrites, sulphuret of lead, &c. Also in many countries of the north of Europe, and in great abundance and purity at Rosalgen in Sweden, where it is manufactured into the best kind of bar-iron, which is extensively imported into this country for choice purposes, and the manufacture of the best steel. That which exhibits the most powerful magnetic properties is found in considerable masses in Sweden, Norway, and China.

Clay Iron-stone.—This is an earthy iron ore, of an ash grey, or brown, sometimes reddish brown colour. Specific gravity 3·35. Analysis by Rd. Phillips, protoxide of iron with a trace of manganese 43·26, carbonic acid 29·30, silica and alumina 20·78, carbonaceous matter 2·67, lime 1·89, water 1·00, loss 1·1. It occurs abundantly in the coal formations of England, Scotland, and Wales, and is the principal source of British iron. This ore generally contains sulphur, from which it requires to be purified by calcination previously to its being smelted in the furnace.

Iron Pyrites, sulphuret of iron.—A mineral of a brass colour, and of brilliant metallic fracture. It occurs in veins and masses in many rocks, and dispersed in beds of clay, investing other minerals, and often penetrating fossil organic substances, and appearing to form the whole of their mass.

It is common in some form or other in almost all mines, and is called by the miners *Mundic*. Specific gravity 4·6. According to Hatchett it consists of iron 47·85, sulphur 52·15. It is the spontaneous decomposition of this mineral which sometimes causes fires in coal pits, and on board of ships on long voyages.

Jade.—A stone of a greyish green colour and very firm texture, consisting of silica, alumina, lime, potash, soda, oxide of iron, oxide of manganese, and water. It is found in many parts of the East, and in the Islands of the Pacific, where one variety of it is used for making axes and merys for warlike purposes, and thence called *axe-stone*. A beautifully carved tortoise of this mineral was found on the banks of the Jumna in India, and is now in the British Museum. From being found also on the banks of the Amazon in South America, it is also called *Amazon stone*.

Jasper.—A siliceous mineral of a dusky red, brown, yellow, and sometimes green colour, opaque and very compact. Composition : silica 75, alumina 0·5, lime 0·2, iron 13. It is found in some of the mines of Cornwall, on the Pentland Hills near Edinburgh, in the older secondary and trap rocks of the Tweed and Clyde, and in several of the Hebrides. There are several varieties of this stone, known by the names *Ribbon jasper*, *Egyptian jasper*, *Porcelain jasper*, &c.

Jet.—A kind of wood coal, which receives a fine polish, found in detached pieces in the aluminous strata of Whitby, and occurs in other marshy and soft strata.

Jura Limestone, or Jura Formation.—The rocks belonging to the oolite formation, including the lias, are so called because they compose the mass of the Jura chain between France and Switzerland.

Kaolin, or Porcelain Clay.—The name *Kaolin* is derived from the Chinese, by whom it was used in making their excellent porcelain many hundred years before the art was known in Europe. It is soft and meagre to the touch, and adheres slightly to the tongue. Specific gravity 2·216, according to Phillips. A specimen from Saxony consisted of silica 52, alumina 37, oxide of iron 6·33. It resists intense heat without fusing. It is found in abundance at St. Austel in Cornwall, mixed with crystals of felspar, mica, and quartz, from which it is separated by washing, and then made into balls and sent to the potteries. It is also found at Meissin in Saxony, near Passau in Austria, and at Limoges in France. The discovery of the composition of the Chinese porcelain has led to the extensive manufacture of this beautiful ware, both on the continent of Europe and in England. By the addition of ground flints and felspar, which are

mixed with the clay, it is capable of that semifusion in the fire which is necessary to produce the ware.

Kilkenny Coal.—See Anthracite.

Killas.—A Cornish term for clay-slate, which contains most of the mineral veins of that county.

Kimmeridge Clay.—A stratum of clay which supports the Portland oolite, so called from the village of Kimmeridge in Dorsetshire.

Lacustrine.—Belonging to lakes; from *lacus*, a lake.

Lamelliferous.—Consisting of very thin plates.

Lamina.—The thin layers of which a stratum is composed; the term is also applied to the thin plates composing a crystallized body, as in the instances of mica and crystals of sulphate of lime (selenite).

Lapis Lazuli.—A mineral of a fine azure blue colour. Specific gravity 2·94. It is compact, fine grained, and hard enough to scratch glass. Composition, according to Klaproth: silica 46, alumina 14, carbonate of lime 28, sulphate of lime 6·5, oxide of iron 3·0, water 2·0. It is found in small masses in primitive rocks, and is brought from China, Persia, and Central Asia. From this mineral is produced the beautiful and costly pigment called ultramarine. By the discovery of the chemical composition of the latter, it is now made artificially, of equal excellence, and at a very low price.

Lava.—The mineral molten matter poured from the craters and sides of volcanos. It is of various colours, yellowish, greenish, grey, and black, is brittle and breaks with a shining fracture, often porous or vesicular, attracts the magnetic needle strongly, and easily fuses into a black glass. A specimen of compact lava from Calabria yielded by analysis, silica, 51, alumina 19, lime 10, soda 4, iron 14, water 1.

Lead.—This metal was well known to the ancients, and has been an article of commerce from the earliest times. It has a bluish grey colour and metallic lustre, but soon tarnishes by exposure to the air, and forms a carbonate of oxide of lead upon its surface of a grey colour. Its specific gravity is 11·381. It is malleable and ductile, has but a feeble tenacity, and fuses at 612° Fahr. When melted in the open air, an oxidized pellicle forms on the surface, which is renewed as often as removed. Litharge is the protoxide of lead, and red led is a peroxide. The lead of commerce commonly contains silver, iron, and copper. The principal ore of lead is Galena, (see Galena.) The preparations of lead: white lead, litharge, red led, muriate of lead, (patent yellow,) chromate of lead, and sugar of lead, are extensively used in the arts.

Leucite.—A mineral found in volcanic rocks, of a white colour, and crystallized.

Lias.—The blue and grey argillaceous limestone between the inferior oolite and the new red sandstone, remarkable for the immense quantity and character of its organic remains, consisting chiefly of Saurian animals and a great variety of extinct shell fish. It is much used for hydraulic lime.

Lignite.—Fossil wood partly converted into coal, as that found at Bovey Tracey near Newton Bushel, Devon.

Lime.—The caustic principle, produced by the calcination of limestone or carbonate of lime. It is composed of one equivalent of the element called calcium 20, and one equivalent of oxygen 8. Lime unites with one equivalent of carbonic acid 22, to form carbonate of lime.

Limestone.—This term taken in its most comprehensive sense would designate a great variety of rocks, the prevailing character of which is that they consist either entirely or chiefly of carbonate of lime in the proportion of one equivalent of lime 28, and one equivalent of carbonic acid 22, or lime 56, and carbonic acid 44 per cent. Most of the ordinary limestones contain impurities, that is, other substances besides carbonate of lime, principally magnesia, silica, alumina, and oxide of iron, which effect both their colour and consistence. Some of the finest crystalline marbles used by statuary present the purest specimens of limestone. Some portions of the chalk also afford a nearly pure carbonate of lime. All the newer secondary limestone rocks contain considerable quantities of silica, alumina, and oxide of iron, and the oolites are so impure as to be unfit for burning, except in particular instances, where they abound in corals. The older limestones, especially those of the carboniferous and the Devonian systems, are more pure, take a fine polish as secondary marbles, and produce, when burnt, excellent white lime.

Lithological.—The stony character of a rock as distinguished from its fossil character.

Lithophytes.—The animals which form coral rocks.

Littoral.—Pertaining to the shore.

Madrepores.—Those corals with star-shaped cavities, of which there are several fossil species.

Magnesia.—A caustic alkaline earth, consisting of one equivalent of magnesium 12, and one equivalent of oxygen 8; united with one equivalent of carbonic acid it forms carbonate of magnesia, which, when pure, is a perfectly white earth.

Magnesian Limestone.—A stone of a sandy, subgranular texture and glimmering face, and of a yellow or buff colour, and is composed of about 30 lime, 21 magnesia, 47 carbonic acid, 1 of clay and oxide of iron. It is much prized as a material for mortar, but is unfit for agriculture except in small quantities. The quarries of Yorkshire and Nottinghamshire afford the

excellent building-stone of York Minster and the new Houses of Parliament.

Magnetic Iron Ore.—See Iron Ore.

Malachite.—Green carbonate of copper. This mineral is found in the copper mines of St. Agnes, St. Austle, and Gunnis Lake, Cornwall, and in Cumberland, in North Wales, in many parts of the old continent, and in America. It is of a bright green colour. Specific gravity 3·5, and according to R. Phillips, is composed of peroxide of copper 72·2, carbonic acid 18·5, water 9·3.

Mammiferous animals, or Mammifers—Those animals which give suck to their young; from *mamma*, a breast.

Mammoth.—An extinct species of elephant, the *Elephas primigenius*, whose remains are found in the gravels of many countries, but most abundantly in Siberia.

Manganese.—Oxide of manganese occurs both compact and crystallized. The compact kind is found near Callington in Cornwall, and on the east bank of the Tamar; it also occurs near Aberdeen, and near Dublin. The ore is of a steel-grey colour passing into black, and consists, according to Vauquelin, of 83·7 oxide of manganese, 14·7 barytes, 1·2 silica, 0·4 carbon.

Marble.—Granular limestone. This substance is, when quite white, a nearly pure carbonate of lime, of a granular crystallian lustre, and of various colours, from pure white to perfectly black. It occurs in most primitive countries, and is thence called primitive limestone. It frequently contains other minerals dispersed through its mass, by which its colour is very much varied, as quartz, garnet, hornblende, talc, asbestos, sulphuret of zinc, and lead, &c. It is found in Glen Tilt, where it is white and grey spotted with green. In the Isle of Skye it is white and veined. It also occurs at Antrim and Londonderry, where it alternates with mica slate and contains mica; and in Slieve Gallion, in the north of Ireland, it contains hornblende. On the coast of Galway a fine grained marble is found more or less stained with serpentine. The purest foreign specimens are the Parian, the Pentelic, and the Carrara. The Parian marble, from the island of Paros, which was much used by the ancients in building and statuary, is large grained and somewhat translucent. The celebrated Venus is of this material. The Pentelic, from Mount Pentelicus, afforded the material for the Parthenon at Athens, of which we have so many fragments in the British Museum. The Carrara marble, brought from the east coast of the Gulph of Genoa, is the material now commonly used by statuary, and is of great purity, and the most delicate whiteness; from this was produced the Antinous of the Capitol, and other celebrated

statues. Saxony, Bohemia, Norway, and Sweden also furnish statuary marble.

Marl.—A mineral abounding in the newer secondary formations, and consisting principally of various proportions of clay and carbonate of lime. Rich marls contain from 30 to 60 per cent. of the latter. Marl has recently been discovered to contain small portions of phosphate and sulphate of lime and potash.

Marsupial animals are such as have a pouch in which they carry their young, of which the most familiar known are the kangaroos.

Mastodon.—A fossil quadruped allied to the elephant.

Matrix.—The natural position of a mineral in its parent rock or stratum.

Meduse.—Marine radiated animals without shells.

Megalosaurus.—A fossil gigantic amphibious animal of the saurian or lizard kind.

Megatherium.—A fossil gigantic animal of the sloth kind.

Metamorphic Rocks.—Those rocks which have undergone a change in their external form and mineral arrangement from the effect of heat. Gneiss and mica slate are supposed to be altered slates, and crystalline or primitive marble altered limestone.

Mercury.—This remarkable metal is sometimes found native in small quantities in primitive rocks, but more commonly in some coal formations of foreign countries. Its specific gravity is 13·6, it volatilizes at a red heat, and becomes solid at 39° below zero of Fahr. Its principal ore is cinnabar or sulphuret of mercury, which is of a bright scarlet colour, and according to Klaproth, is composed of mercury 84·5, sulphur 14·75. It is principally found in Hungary, Carniola, and Spain.

Mica.—This mineral is found disseminated in rocks in thin plates and crystals, and generally forms one of the materials of granite, and always of mica slate and gneiss. It also occurs more sparingly scattered through strata of the secondary order, particularly in the millstone grit and the sandstones of the coal formation. It is generally disposed in thin laminae, which are of a metallic lustre, easily split with a knife, and of various colours, white, yellow, green, brown, and black. Specific gravity 2·7. Composition: silica 46·10, alumina 31·16, potash 8·39, fluoric acid 1·12, oxide of iron 8·65, water 0·87. Other specimens afford considerable variations from this analysis. A mica found in Russia occurs in plates of more than a yard in diameter, and being transparent is much used as a substitute for glass in windows, more particularly for ships, as being less liable to fracture from the discharge of cannon. In some specimens

the plates admit of such extreme subdivision as to be no more than $\frac{1}{100000}$ of an inch in thickness.

Mica Slate.—A metamorphic sedimentary rock of the primary order, consisting of crystals of quartz, felspar, and mica, with an excess of the latter. It forms vast mountain masses in many parts of the world, and constitutes a considerable portion of the North of Scotland.

Miocene.—The middle portion of the tertiary deposits.

Molasse.—A greensand with marl and conglomerates of the tertiary formation, and occurring extensively in Switzerland.

Molecules.—Very minute particles, whether elementary or compound.

Mollusca or Molluscous Animals.—Such animals as have soft bodies and no bones. All shell-fish are so called, from *mollis*, soft.

Monocotyledonous.—A great division of the vegetable kingdom, distinguished by the seed having only one lobe, as the palms, grasses, &c.

Mountain Cork.—A mineral so light as to swim in water, and composed of silica, alumina, lime and magnesia. Mountain leather, mountain wood, and asbestos are of similar composition, and so named from their peculiar external character.

Mountain Limestone.—The limestone rock which forms the lowest member of what is called the carboniferous system, and thence often called carboniferous or coal-bearing limestone.

Mocha Stone.—A translucent agate, containing vegetable filaments or substances which much resemble them.

Muschelkalk.—The German name for a limestone belonging to the new red sand-stone formation, but not found in England.

Naphtha.—A mineral inflammable fluid, of which there are many springs: most probably a production of coal.

Natron—Carbonate of Soda.—This salt is found in the lakes of Egypt and Hungary. When pure it consists, soda 22, carbonic acid 15, water 62. An impure kind called trona is found at Tripoli and Fezzan in Africa, and is composed of soda 27, carbonic acid 28, water 2·27, and sulphate of soda 2½.

New Red Sandstone, or red marl.—The designation of a series of strata between the lias and the coal measures, consisting of sandstone, clays, or marls, with beds of rolled stones. The characteristic colour is red, but the sandstones and marls are often of a greyish green, and sometimes almost white.

Nitrates.—Salts produced by the union of nitric acid with bases, of which the nitrate of lime, nitrate of potash (nitre), and nitrate of soda are common instances.

Nitre—Nitrate of Potash.—This well-known salt is found native in France, Italy, Hungary, and many other parts of Europe, also in Arabia, Persia, and India, the Cape of Good Hope,

and Kentucky in America. It is also made artificially by the mixture of animal and vegetable substances with old plaster, or other calcareous matter, by the fermentation of which nitrates are produced, and these after having been extracted by water and purified by crystallization afford the nitre of commerce. In this process the vegetable and animal matter undergo decomposition, and the nitrogen they contain unites with oxygen in the proportion of 5 equivalents of the latter to 1 of the former to form nitric acid, which combining with the potash present, produces nitre, and with lime produces nitrate of lime; to complete the manufacture the lime is replaced by potash, and the process completed by crystallization.

Nitrogen.—The indifferent, or diluting principle of the atmosphere, commonly called azote. Also one of the elements of most vegetable and animal substances, but chiefly abounding in the latter. With oxygen, nitrogen forms nitrous oxide and nitric acid; and with hydrogen, ammonia.

Nickel.—A metal of steel grey colour, generally united with cobalt and arsenic. It is found in the mines of Cornwall, and the lead mines of Scotland, and in several parts of the continent. Meteoric iron always contains some portion of nickel.

Nucleus.—Any central substance round which other matter assembles.

Obsidian.—A glassy volcanic mineral, of a greenish or dark-brown and black colour; specific gravity, 2.35. A specimen from Mount Hecla yielded by analysis, silica 78, alumina 10, lime 1, potash 6, oxide of iron 1. It is found abundantly in volcanic countries, and is sometimes called volcanic glass.

Old Red Sandstone.—One of the older secondary formations, next in order beneath the mountain limestone and carboniferous series, with which it has been sometimes associated, but is now considered as a member of the Devonian series. It consists of dark-red sandstones, clays and limestone. The sandstones are schistose, and much firmer than those of the new red sandstone.

Onyx.—A siliceous stone, a species of chalcedony, distinguished by opaque white stripes or layers.

Oolite, or Roe-stone.—So called from the resemblance of its molecules to the roe of fish. The oolites form extensive secondary strata of imperfect limestones, between the chalk and the lias formation, extensively quarried for building purposes; the most valuable of which are the Portland, or upper oolite; the Bath, or great oolite; and the inferior oolite. These rocks all abound in organic remains.

Opal.—Of this stone there are three or four kinds, but they are all nearly alike in composition, consisting chiefly of silica

and water. Noble opal is of a whitish or yellowish-white colour; but when held to the light, the transmitted colours present beautiful variations of green, blue, yellow and red. Specific gravity, 2.110. A specimen from Hungary yielded 90 parts of silica, and 10 parts of water. The quantity of water is supposed by Berzelius to depend upon the state of the atmosphere, and to vary with it. Common opal is of various shades of white, green, yellow and red, but exhibits no play of colours, like the noble opal; besides silica and water, it contains a small portion of oxide of iron. It is found in some mines near St. Day, in Cornwall, and in the north of Ireland; also in many countries of Europe, and in some parts of America.

Organic Remains.—The remains of animals and plants found in a fossil state.

Osseous Breccia.—Fragments of bones cemented together by stony matter. Often found in limestone caverns.

Outliers.—Those detached portions of strata which stand out from the main body, and appear to have been separated by the denudating force of water; and resembling those heaps or portions of a bed of earth left by excavators to indicate what has been removed.

Oxides.—Substances produced by the chemical union of oxygen with other elements or their compounds. Rust of iron and red lead are familiar instances of oxides of metals. The alkalies and earths are oxides of metals, or metal-like elements. In numerous instances metals unite with two or more proportions of oxygen; such compounds are distinguished from the simple oxide by the term *per-oxide*, as peroxide of iron, peroxide of lead, peroxide of manganese, &c.; the term peroxide always signifying that the compound contains the greatest quantity of oxygen the oxidized substance is capable of uniting with, and protoxide the least.

Oxygen.—The most abundant and important element in nature; as in a solid state, it constitutes about one-half of the rocks which form the crust of the earth; and in a gaseous form, above one-fifth of the atmosphere: in the latter state it is the active agent for the support of animal life, and of the combustion, as well as the decomposition by decay of vegetable and animal substances.

Pachydermata.—Quadrupeds are so called which have thick skins, such as the elephant, rhinoceros, horse, &c.

Palæontology.—The science of fossil remains, from two Greek words, signifying the study of ancient beings.

Palladium.—A very rare metal, found united with, or alloyed with platinum, and somewhat resembling it in appearance. Specific gravity, 11.8.

Parian Marble.—See Marble.

Pelagian.—Signifying deep sea.

Pentelic Marble.—See Marble.

Peroxides.—When an oxidisable substance is combined with the greatest quantity of oxygen it is capable of uniting with, it is called a peroxide of that substance; as peroxide of iron, peroxide of manganese, &c.; and is opposed to protoxide, which is an oxide in the least degree.

Petroleum, or Mineral Tar.—A thick black semi-fluid, resembling tar, but rather thicker. It is very combustible, and burns with a thick smoke, leaving a little black coaly residue. It is evidently the production of coal beds. It occurs at Ormskirk, Lancashire; Coal Port, Colebrook Dale, Shropshire; near Edinburgh; and in one of the Hebrides: it is also found in Bavaria, Switzerland and Italy, in many other parts of Europe, and in America.

Phosphates.—Salts formed by the union of phosphoric acid with bases.

Pipe Clay.—A nearly white clay, which adheres very strongly to the tongue, and is very plastic. It is infusible, and is used for the manufacture of pipes, and, in the potteries, in the production of queen's ware. It is found extensively in the plastic clay on the coast of Dorset, and particularly about Poole.

Pisolite.—A stone resembling a mass of peas.

Pitch Stone.—A black unstratified rock of an unctuous feel and pitch-like appearance.

Plastic Clay.—The lowest member of the tertiary strata, resting upon the chalk, and composed of numerous beds of clay, sand and flinty pebbles.

Platinum.—A valuable metal, greatly resembling silver in appearance, but much harder; though malleable, perfectly infusible; specific gravity, 21·47. It is found in the gold-mines of Peru and Brazil, and in Russia. It occurs in separate small masses, or grains, and also alloyed with gold and other metals. From its infusibility, and its resistance to the action of oxygen and the mineral acids, it is a most valuable metal in many of the operations of chemistry, the knowledge of which has been greatly extended by its discovery.

Plesiosaurus.—A fossil extinct amphibious animal of the lizard tribe, with very long neck.

Pliocene.—The newer tertiary formation, to which the mammiferous Crag of Norwich, and the Till of the Clyde Valley, belong, and also the deep sub-Apennine and Sicilian tertiary deposits, and brown coal beds of Germany.

Plumbago.—See Graphite.

Plutonic Rocks.—The rocks so called are granite and those other unstratified masses which appear to have been formed from a molten state, and to have cooled and consolidated at great

depths from the surface, and consequently under enormous pressure of the incumbent strata, and perhaps of the ocean.

Porcelain Clay.—See Kaolin.

Porphyry.—An unstratified igneous rock, in which detached crystals of felspar are diffused through a compact mass of that or any other mineral, exhibiting a spotted appearance.

Portland Stone.—A stratum of the upper oolite, which affords the valuable building-stone most generally used in the ornamental buildings of London.

Potash.—The oxide of a brilliant metal called potassium. The deoxidation of this substance requires the most energetic action of the galvanic pile; and such is the powerful affinity of this metal for oxygen, that upon being thrown into water, so rapidly is the decomposition of the latter effected as to produce instant and violent combustion. United with silica or lime, potash is a minor constituent of almost every kind of rock, and of all soils; and is indispensable to the support, both of vegetable and animal existence.

Potter's Clay.—A plastic clay, of various colours in different localities, and found in many different strata. When mixed with sand, it is the material of which bricks and tiles are made. The clay used in the potteries of Staffordshire and Newcastle-upon-Tyne is chiefly brought from the coast of Hampshire, Dorset and Devon; and a clay used for coarse potter's work is dug in the plastic clay formation at Reading, and the London clay, at Lambeth, London. The Hampshire clay affords by analysis—silica 51, alumina 25, lime 3, a trace of manganese, and some water. A kind of clay found in France, which bears intense heat without fusing, and is therefore used for the tiles and frames in which porcelain is baked, consists of a greater portion of alumina than the above, of which the following is the analysis—silica 43, alumina 33, lime 3, iron 1, water 18. A clay found near Stourbridge is one of the most infusible, and is extensively used for making bricks and in the construction of iron furnaces and boiler fire-places.

Primitive Limestone.—See Marble.

Pudding Stone.—See Conglomerate.

Pumice.—A light porous lava.

Purbeck Limestone.—An imperfect limestone, belonging to the Wealden formation, found in the island of Purbeck; and much used for building, and for laying floors and making troughs, &c.

Puzziolana.—Volcanic ashes, very valuable for making mortar. It is obtained at Puzzioli, in the Bay of Naples, and is extensively used in the south of Europe.

Pyrites.—Mineral substances in which sulphur is combined with

metals, chiefly iron, copper, and lead, and which are called sulphurets of those metals. See Iron Pyrites.

Pyroxene.—See Augite.

Quartz.—A German name for stone composed of pure silica, the most abundant mineral substance in nature, of which rock crystal is a perfect specimen. Flints, agates, chalcedony and cornelian, are composed almost entirely of quartz. All stones consisting principally of quartz have the property of scratching glass. Its specific gravity is 2·6; and it crystallizes in six-sided prisms, terminated by six-sided pyramids, which are said to contain from 2 to 3 per cent. of water, which, according to Berzelius, varies with the state of the atmosphere. Most beautiful crystals of quartz are constantly found in the veins and cavities of metalliferous rocks; and some of the finest and most transparent occur in the slate quarries of Delabole, on the north coast of Cornwall; but the largest specimens are brought from Dauphiné, Madagascar and the Alps. Sometimes crystals of quartz occur which enclose water, air, and even bitumen. It also contains frequently several mineral substances. Quartz is associated with, and forms a part of the ores of most of the metals, and is the principal constituent of almost all the older and crystallized rocks.

Quicksilver.—See Mercury.

Realgar.—A sulphuret of arsenic. Its specific gravity is 3·3; and it consists of arsenic, 69; sulphur, 31. It is of a brilliant red or scarlet colour.

Red Marl.—A name often given to the new red sandstone formation, from its principal member consisting of a deep stratum of red clay or marl.

Reddle, or Red Chalk.—A red ponderous earthy mineral, containing much peroxide of iron; much used for marking sheep, and as an ingredient in coarse paints. It occurs at St. Just, at the extremity of Cornwall. Specific gravity, 3·3 to 3·8.

Rotten Stone.—A soft earthy substance, much used for polishing, consisting of alumina 86, silica 4, carbon 10. It is found at Bakewell, in Derbyshire.

Ruby, Oriental.—A beautiful red crystallized mineral, a variety of corundum. It consists of alumina 90, silica 7, oxide of iron 1·2.

Salt, Common.—Chloride of Sodium. This well known substance is found in vast masses, in many parts of the world, sometimes composing entire mountains, and in some instances at great elevations above the level of the sea. The salt of England is supplied from the thick beds of rock-salt in Cheshire, and the brine springs of Droitwich. Pure salt consists of 1 equivalent of sodium 23, and 1 equivalent of chlorine 35. It is, how-

ever, seldom or never found pure; but contains variable portions of sulphate of lime, and muriates of lime and magnesia. Salt is so abundant that it is found in all waters, but especially in the sea, the water of which contains about a thirtieth part in solution, which may be considered as the great magazine from which the salt deposits have been derived. In England all the salt required, both for home consumption or export, is derived from brine-springs and salt mines. Previous to the year 1670 the principal supply of salt was obtained from the salt-springs of Droitwich, but at that time rock salt was discovered by an unsuccessful seeking for coal in Cheshire, and enormous quantities have for a long time past been raised from the mines sunk into it. From one locality alone upwards of 60,000 tons are annually raised, most of which is exported, and the remainder dissolved in water, and crystallized. The rock salt is extracted from these mines much after the same manner as coals, by leaving thick pillars at certain intervals, but the intervening masses are loosened by blasting, and the fragments brought to the surface as from a coal-pit or a quarry. The salt so extracted is more or less stained and rendered impure by the red marl in which it is found deposited, and the fragments present a dull reddish appearance. The salt-springs, and also the mines of rock salt, are confined in England to the new red sandstone formation, generally interstratified with thick beds of gypsum; but in other countries of Europe it is sometimes found in strata of much more recent date. The brine-springs in Cheshire are in some instances so rich as to yield nearly one-fourth of salt, which they obtain by rising through thick deposits of rock salt. Some of the most remarkable foreign salt mines are those of Altamonte, in Calabria; Halle, in the Tyrol; Cardona, in the Pyrenees; and Wieliczka, in Poland; of which the latter is the most extensive. At this mine the shaft is sunk about 200 feet, through beds of sand, limestone, gypsum, variegated marl, and schist; from the first stage the descent is continued by wooden stairs. The first gallery exhibits the remarkable circumstance of a subterranean chapel, excavated in the mass of the chalk, 30 feet in length, 24 in breadth, and 18 feet high; the pillars which sustain the roof, as well as the altar, crucifix and statues, are wrought out of the same material. The blocks of salt are generally cut out of the solid mass by similar mechanical means as those employed in quarrying masses of stone, namely, by forming a line of holes into which wedges are introduced and driven simultaneously, by which the blocks are detached of the required form and size. Gunpowder is also used in *this mine*, and will probably altogether supersede the more

tedious mechanical process. Nearly 2,000 men are constantly employed in this stupendous mine, and the galleries are said to extend more than eight miles in length.

The mode of purifying the salt is effected in a similar manner at all salt mines and springs. When a brine of sufficient strength is obtained, and has become clear, it is put into evaporating pans, when it is soon brought to the boiling point; the impurities which rise to the surface are skimmed off, and thrown aside for agricultural purposes, as are also the first crystals that form. The boiling is continued for many hours, during which the crystals are deposited as the water diminishes. When the water is much reduced the salt is raked out, and put into moulds, which are placed in a drying stove till the salt is sufficiently dried to be removed for sale. To produce very fine salt a slower process of evaporation is adopted.

Sea salt, called bay salt, is obtained by evaporating the sea-water in extensive evaporating pans, by the heat of the sun. This salt contains many impurities, as will be seen by the following analysis, by Marset; according to which, 1,000 parts of sea-water contain—

Chloride of sodium (common salt)		26·660
Sulphate of soda		4·660
Chloride of potassium		1·232
Chloride of magnesium		5·152
Sulphate of lime		1·500

39·204

Sapphire.—See Corundum.

Satin Spar.—A fibrous carbonate of lime, of silky surface, and capable of receiving a fine polish. It is found near Alston Moor, Cumberland, in veins in clay shale, and in Glen Tilt, Scotland.

Saurians.—Enormous aquatic animals of the lizard kind, now perfectly extinct, whose fossil remains abound in the blue lias formation, and more or less in all the secondary strata above the lias. Several large and perfect specimens of these are exhibited in the British Museum; and many vertebræ, of about six inches in diameter, which must have belonged to others of more gigantic dimensions. So abundant were these animals during the deposition of the newer portion of the secondary strata, that their dung has enriched these rocks with phosphate of lime.

Schist.—A German term for slate, in England sometimes applied to clay slate; by the miners of Cornwall called Killas.

Schistose.—Having a slaty, or laminated, fracture.

Schorl.—This mineral is of a brownish or black colour, and

occurs massive, disseminated and crystallized; but it is mostly aggregated, and occurs in beds. The crystals are often minute and divergent. Specific gravity, 3·2. Composition, silica 38, alumina 34, magnesia 1, potash 6, oxide of iron 21. It is found in Perthshire, Banffshire, Invernessshire and Argyleshire, Scotland; and in the granite and tin mines of Cornwall, and is called by the miners "cockle;" also in the granite of the east of Ireland.

Scoriæ.—Cinders ejected from volcanos.

Secondary Rocks.—The extensive series of rocks or strata intermediate between the tertiary and the primary.

Sedimentary Rocks.—Those strata which have been mechanically deposited by water. All the stratified rocks are called sedimentary.

Selenite.—Crystallized Gypsum, which see.

Septaria.—The name given to the nodules and layers of argilliferous limestone, found in the London clay and other strata; which when calcined forms the cement powder so extensively used for plastering walls, and in decorative architecture, in London. The nodules are of a bluish-brown colour, and are traversed by veins of crystallized carbonate of lime; it is composed of, carbonate of lime 68, siliceous 18, alumina 7·5, oxide of iron 2, carbon and bitumen 3, water 5. When the calcined powder is mixed with water, the alumina causes it to set quickly, which renders it so valuable as a cement; for which purpose it is generally mixed with two parts of sand; but in the construction of the Thames Tunnel it was used alone.

Serpentine.—Belonging to the metamorphic rocks; so called from its various colours, which are dark green, yellow, grey and brown. It principally consists of a silicate of magnesia, combined with lime, water and oxide of iron. Its analysis, according to Hisinger, is magnesia 37·24, silica 32, alumina 0·5, lime 10·2, water 14. Its fracture is splintery, with a glimmering surface, and somewhat soapy to the touch. Specific gravity, 2·2. It occurs in the marble of Glen Tilt, in Scotland; the Lizard, in Cornwall; and in primitive marble on the coast of Galway, Ireland. It is the colouring matter of the celebrated marble called Verd Antique, so highly prized by the ancients, but the quarries of which are now lost.

The above serpentine is called Noble Serpentine; there is another kind called Common Serpentine, which is of various shades of green, brown and red, variously mixed. Specific gravity, 2·5. Analysis, according to Vauquelin, magnesia 44, silica 44, alumina 2, oxide of iron 7·3, oxide of manganese 1·5, oxide of chrome 2. It occurs at Portsoy, in Banffshire, and several other parts of Scotland; and in the Hebrides.

and Shetland Islands; and also in the tract called the Lizard, in the south of Cornwall.

Shale.—Indurated slaty clay.

Shingle.—A term given to pebbles, or water-worn stones, on the sea shore.

Sienite.—A kind of granite in which the mica is replaced by hornblende; from Syene, in Upper Egypt, where that rock forms the cataracts of the Nile.

Silex.—The earth of flints; the chief component of most sands.

Silica—*Silicic acid*.—A pure earth, of which rock crystal is a perfect specimen. The most abundant earth in nature, as it is the principal ingredient in most of the great mountain masses. It is composed of silicon 8, and oxygen 8.

Silicates.—Substances formed by the combination of silica with alkaline and earthy bases, in which silica plays the part of an acid. Thus we have silicate of soda or potash, (glass,) silicate of alumina, lime, magnesia, iron, &c.

Siliceous.—Flinty, or composed of flinty particles.

Silicified.—Petrified by silicious matter.

Silt.—The finely divided matter carried down and deposited by rivers, and forming what are called alluvial soils on their banks, and deltas at their mouths.

Silver.—This valuable metal occurs in a native state, and united in numerous ores with other metals, and very generally in the ore of lead.

Native silver is of a pure white, but tarnished externally with a grey or black colour, owing to the presence of sulphur. It is soft, flexible and malleable. Specific gravity about 10. It is found in several mines in Cornwall, in Huel, Mexico; Perranzabulo, Dalcoath Mine; Huel Duchy, near Callington; Huel St. Mark, near Calstock, and several others. It occurs also in Scotland; and the mines at Alva, in the Ochill Hills, are said to have yielded 40,000*l.* or 50,000*l.* worth of silver. It has also been found in the clay slate of Ireland. The British mines, however, yield but an inconsiderable quantity of silver; and until the discovery of America, the mines of Saxony, Hungary and Transylvania, and the trade with the east, afforded the supplies of that metal to Europe. The immense quantity of silver ore discovered in America, and the comparative facility with which it was raised, permanently effected a reduction of its relative value. Prior to that time the comparative value of silver and gold was as 10 of the former to 1 of the latter; whereas since that period the relation has been as 16 to 1. This cheapening of the value of silver is owing to the abundance of the ores in the American mines, as they are not richer in metal than those of Europe, the richer veins not yielding more than about four ounces to the hundred-weight of ore.

while the mines of Saxony, at fortunate periods, have yielded from 10 to 15 ounces. In the celebrated mining district of Mexico, Guanaxuato, one vein alone, the Vetí Madre, is stated to have furnished annually for a great number of years, about three hundred pounds weight of silver, besides a great quantity of gold; and the mines of Potosi, in Peru, yielded from their first discovery, up to the year 1803, silver amounting to 237,358,354*l.* sterling, which had paid the royal duties; and no doubt an immense quantity had been taken away which had not passed the mint. The ores of these mines are carried to the surface upon the backs of the Indians, who for many hours each day ascend the steps of deep mines, with a load of 200 pounds and upwards. Silver is found often mineralized with sulphur and carbonic acid, and combined with several metals, amongst others, gold, copper, antimony, iron, lead, and arsenic, mixed with silice and alumina.

Simple Mineral.—A term applied to minerals to distinguish them from rocks, which generally consist of an aggregate of minerals. The minerals themselves so called are nevertheless compounds of different elements.

Slate Clay.—Indurated and laminated clay; often intervening between the stony masses of the strata, and abundant in the coal measures.

Soap Stone.—An unctuous feeling stone, which when first dug is soft, but by exposure and the loss of moisture becomes hard. It is mostly white, or grey, and yellow, veined with green and purple. It occurs in the serpentine of the Lizard, Cornwall, where large lumps of native copper were found in the same vein. The soap stone of Cornwall consists of silica 45, alumina 9.25, magnesia 24.75, potash 0.75, oxide of iron 1, water 18. It fuses into a white enamel; and at Swansea is much used in the manufacture of porcelain.

Soda.—See Natron.

Sodium.—The metallic base of soda, which is an oxide of sodium, and of common salt, which is a chloride of sodium.

Solfatara.—A volcanic vent emitting water, sulphur, and acid vapours.

Spar.—A term given to several crystalline earths. Crystals of carbonate of lime are called calcareous spar; the fluoride of lime, Derbyshire spar; the crystals of quartz are often called spar.

Specular Iron.—An oxide of iron, containing 69 iron, and 31 oxygen; it occurs in the killas of the mines of Cornwall, and also in Scotland. The island of Elba, on the coast of Italy, affords great abundance of this ore; where it has been worked from the remotest times.

Stalactite.—The pendent, and often tube-like, masses of carbonate of lime, seen projecting from the roofs of caverns, and some-

times of rocks; and produced by water percolating from above, and holding carbonate of lime in solution.

Stalagmite.—A deposit of carbonate of lime on the sides and floors of limestone caverns.

Steatite.—A magnesian mineral, of various shades of white, grey, yellow, green and red; it is unctuous to the touch, and of a splintery fracture. Composition, silica 64, magnesia 22, oxide of iron 3, water 5. Specific gravity, 2·67. It is found at Portsoy, in Scotland, in serpentine; in the Isle of Skye, and other islands of the same group; it also occurs in the Isle of Anglesey. It is found in the primitive rocks of Saxony, Bohemia, Norway and France, most commonly in serpentine. When calcined it is employed in the manufacture of the finest porcelain. From its unctuous property it is said to be used by the Arabs in their baths, instead of soap, to soften the skin; and Humboldt mentions that a race of savages, on the banks of the Orinoco, mix a species of steatite with their food, or eat it alone, as a substitute; or rather, it must be supposed, to assist to distend the stomach.

Stone Coal.—See Anthracite.

Stratified.—Formed in thick beds, or laminated masses, called strata.

Stratum, plural Strata.—A layer or bed of rock.

Strike.—The horizontal direction or line of bearing of the face of strata, or of the slope of a line of hills.

Sulphur.—This combustible mineral occurs massive, disseminated and crystallized; often investing and penetrating other minerals; and in veins and beds in primitive rocks, in many parts of the world. The kind called volcanic sulphur is found near the craters of volcanoes. Many volcanoes yield it in great abundance, particularly those of the Andes in South America. The source from which Europe is principally supplied is a sunken plain near Naples, called the Solfatara, from whence it has been raised upwards of 2,000 years.

Swinestone, or Stinkstone.—A carbonate of lime, of a dark or black colour, which when scratched gives out a fetid smell, which appears to arise from the liberation of sulphuretted hydrogen. When calcined it produces a beautiful white lime. It is found chiefly in the mountain limestone, from which it differs only in the particular above mentioned. It is found at Clifton, near Bristol; in the Mendip Hills, Somerset; in Shropshire and Northumberland, and also in Derbyshire, where it is very abundant. The same kind of carbonate of lime is found in a soft bed of magnesian limestone, in detached masses of inconsiderable size, at Hartlepool, and on the coast, near Sunderland.

Synclinal Axis.—The direction of the hollow between two ranges

of hills which have been formed by the partial elevation of the strata; the anticlinal axes having relation to the ridges of those hills.

Talc is a shining, semi-transparent, soft mineral, of an unctuous feel; of a white or yellowish colour. It is separable into thin laminæ, which are very flexible, but not elastic; by which latter character it differs from mica, which in other respects it much resembles. Massive talc is less translucent and flexible than the crystalline. Specific gravity, 2·77. Composition, silica 61, magnesia 30·5, potash 2·75, oxide of iron 2·5, water 0·5. It is found at Glen Tilt, Perthshire, in granular limestone; in Banffshire and Aberdeenshire, in serpentine; at the Lizard, Kyan's Cove and Porthaller, Cornwall. It is also found in primary mountains in several parts of the continent of Europe.

Talus.—A bank formed at the foot of a rock, from the debris or fragments which have fallen from it.

Tellurium.—A rare metal, found only in small quantities, in the gold mines in Transylvania. It is described as a white metal, approaching to a lead grey; of metallic lustre, and laminated structure; and is usually found alloyed with gold, silver, and iron.

Tertiary Strata.—The series of strata above the chalk formation, all of which exhibit in their organic remains a wide departure from those contained in the chalk and other secondary strata beneath, and their approximation to the character of the animals which now inhabit the sea.

Testacea.—Soft or molluscous animals enclosed in a shell, such as snails, oysters, mussels, &c.

Tin.—The ores of this metal are but few, and that from which almost all the tin of commerce is derived is the oxide of tin, which is found more abundantly in Cornwall than any other part of the world, from whence it was obtained by the ancients at a very remote period. The oxide occurs mostly in crystals, more or less transparent, coating cavities and veins; also fibrous and granular. It is found principally in veins traversing clay slate and granite; and is generally most abundant where these two rocks meet, accompanied by many other minerals. It occurs disseminated in the granite of St. Michael's Mount. Large quantities of the oxide of tin are also obtained from the diluvial beds in the valleys, by an operation which is called streaming; the ore being separated from the earthy matter by means of streams of water artificially managed; and the ore thus obtained is a very pure oxide, and produces the best tin. The specific gravity of oxide of tin is 6·7; and a specimen analysed by Klaproth, consisted of tin 77·5, oxygen 21·5, oxide of iron 0·25, siliceous 0·75. Copper and arsenic are also found in the ores

of Cornwall. When the tin ore is extracted from the mines, the crystals are mixed up with the slate and granite, sulphurets of iron and copper, arsenical pyrites, and other minerals.

Pure tin has a white colour, and a lustre resembling that of silver, which does not readily tarnish when exposed to the air. Specific gravity, about 7.3. It is malleable, and may be beaten into laminæ not exceeding $\frac{1}{1000}$ th part of an inch in thickness. It is less tenacious than several other metals, and when bent gives a crackling noise; it fuses at 442° ; and if exposed to the air at that temperature, the surface tarnishes, by the formation of oxide of tin. At a white heat it burns with a white flame, being converted into a peroxide of tin. It forms with other metals various valuable alloys: with copper, bell-metal, and speculum-metal; and with zinc, brass.

Toadstone, or Amygdaloid.—A cellular trap, or igneous rock, principally consisting of felspar. The cells are generally filled with mineral matter of a different colour to the mass, which imparts that spotted or porphyritic appearance by which it is principally characterised.

Topaz.—This stone is found massive and crystallized. It is sometimes nearly transparent, and of various shades of yellow, green, blue, lilac and red. Brazilian topaz, according to Vauquelin, consists of alumina 50, silica 29, fluoric acid 19. It is the product only of primitive countries, chiefly of veins. It is found in small whitish or greenish crystals, in the granite of St. Michael's Mount, and in a mine near St. Agnes, and in alluvial soil at Cairn Gorm, Aberdeenshire. It occurs also in Bohemia, Saxony, the Uralian mountains of Russia, Siberia, Savoy, and North and South America.

Tourmaline.—A crystallized mineral which occurs of various colours, white, green, blue, and black; those of the two former colours are partly translucent, the black are opaque. Analysis of a specimen from Sweden, by Gmelin, afforded silica 42.59, alumina 34.32, magnesia 8.47, potash and soda 2.42, oxide of iron 5.22. White and green tourmaline are found at St. Gothard, Switzerland; green comes from Ceylon; and those of an indigo blue colour occur in the mine of Atoc in Sweden; and black or brownish-black tourmaline occurs in most of the primitive tracts of Europe and America. It also occurs at St. Just, Cornwall, and splendid crystals of it have been discovered in a red granite at Bovey Tracey, Devon.

Trachyte.—A volcanic product composed of glassy felspar with detached crystals, which make it resemble porphyry.

Trap Rocks.—A class of unstratified igneous rocks, so called from

their sometimes exhibiting on their surface the resemblance of steps, (*trappa* being the Swedish name for step.) The principal of these rocks are amygdaloid, dolorite, green stone and basalt. These rocks have evidently in a molten state penetrated and upheaved the regular strata of all ages, and have been the cause of their displacement, forming extensive dykes and faults in the mining districts.

Travertin, or Tufa.—The stony matter deposited by springs containing carbonate of lime in solution. These deposits are so copious in some of the small lakes of the South of Italy, that they have supplied building material for the most ancient and colossal structures of that country. By those changes which in remote times have affected the surface of the earth, the bottoms of lakes have been elevated, and the travertin deposited in them raised to a considerable height above the level of the sea. Thus the seven hills of Rome, which now rise more than 200 feet above the level of the Tiber, appear to have once formed the bottom of a lake, as they are capped with these deposits of travertin. So rapid is the formation of travertin now in operation, that Sir Charles Lyell, describing the baths of San Filippo, says, "the water which supplies the baths falls into a pond, where it has been known to deposit a solid mass thirty feet thick in about twenty years." A manufacture of medallions is carried on at this place. This water is conducted by canals into several pits, in which it deposits travertin and crystals of sulphate of lime. After being thus freed from its grosser particles, it is conveyed by a tube to the summit of a small chamber, and made to fall through a space of ten or twelve feet. The current is broken in its descent by numerous crossed sticks, by which the spray is dispersed around upon certain moulds which are rubbed lightly over with a solution of soap, and a deposition of solid matter like marble is the result, yielding a beautiful cast of the figures formed in the mould.

Tripoli.—A siliceous mineral of argillaceous aspect, which occurs either massive or slaty. It is composed almost entirely of silica, derived, according to the discoveries of Ehrenberg, from shields of microscopic animalculæ, so minute that a cubic inch is computed to contain forty millions of them. It was formerly brought from Tripoli in Africa, from which it derives its name; it is now, however, found in several parts of Europe. This substance is extensively used for polishing metals, marbles, glass, &c.

Veins.—Fissures or cracks in rocks, generally filled up by materials differing from the rock, and often containing the ores of metals; these are sometimes several yards wide, and at

others branch into very narrow divisions, resembling the veins of an animal, whence their name.

Zeolites.—A family of simple minerals usually found in trap or volcanic rocks, as stilbite, mesotype, &c.

Zinc.—There are several ores of this metal, though they are not numerous; the principal are the sulphuret of zinc called blende, which has been described under that name, and the carbonate of zinc or calamine. The latter, which affords the zinc of commerce, occurs in beds and veins of secondary limestone in several countries of Europe. It is very abundant in England, and is found in the Mendip Hills at Shepham near Cross, Somerset; at Holywell, Flintshire; and in Derbyshire. It occurs both crystalline and compact. The compact calamine consists of oxide of zinc 68·4, carbonic acid 35·2.

Zinc, when freed from its mineral impurities, is a metal of considerable hardness, with a strong metallic lustre and bluish white colour. Specific gravity 7. At both a low and high degree of heat it is brittle, but at a temperature between 210 and 300 it is malleable and ductile, and may be rolled into thin sheets. It is little affected by the action of air and moisture, but when fused in open vessels it absorbs oxygen, and produces the white oxide called the flowers of zinc. Its combining proportion or equivalent is 32.

Zoophytes.—Aquatic animals which produce corals, sponges, &c., and are found abundantly in the seas of tropical and warm climates.

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